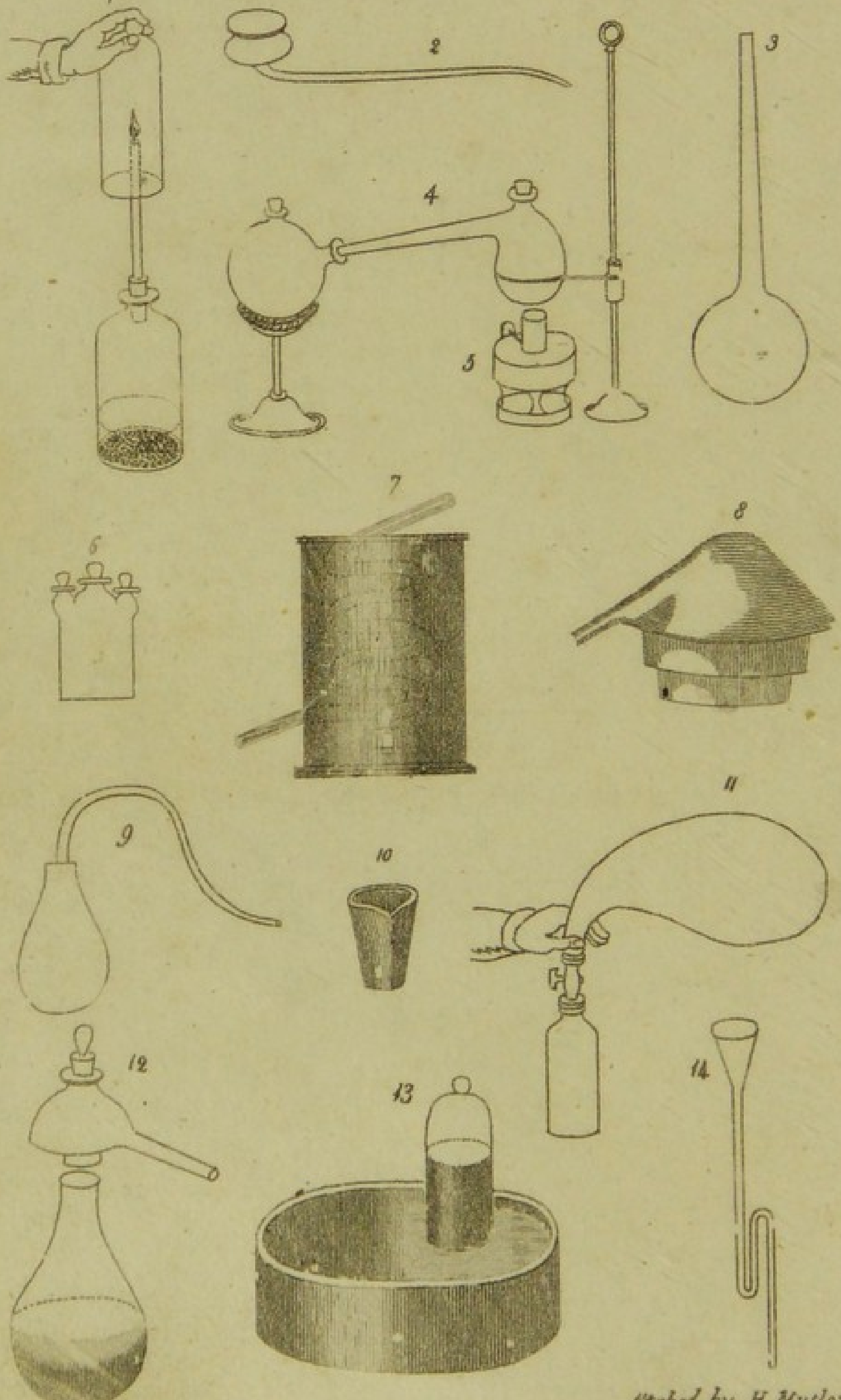
A chemical catechism, with copious notes, a vocabulary of chemical terms, useful tables, and a chapter of instructive and amusing experiments / By Samuel Parkes.

Etched on Glaſs by Fluoric Acid
for the Chemical Catechism.



Etched by H. Mutlow.

A
CHEMICAL CATECHISM,

WITH

COPIOUS NOTES,

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VOCABULARY OF CHEMICAL TERMS,

USEFUL TABLES,

AND

A CHAPTER

OF

INSTRUCTIVE AND AMUSING EXPERIMENTS.

BY

SAMUEL PARKES,

MANUFACTURING CHEMIST.

THE SECOND EDITION,

WITH CONSIDERABLE ADDITIONS.

LONDON:
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ST. JAMES'S-STREET; A. BLACK, EDINBURGH, AND
M. KEENE, DUBLIN.
1807.

"As public opinion is daily becoming more liberal, it may begin to be felt, that of all possible methods of consulting happiness, to withhold information for the sake of adding to fortune, is the most preposterous. A few additional hundred pounds, well laid out upon the BOY, may more improve the condition of existence, than the mines of Potosi bequeathed to the MAN. The ill-advised niggardliness of Parents is one principal cause why Genius has so seldom been exerted upon the means of *early* instruction."
BEDDOES.

"Chemical research conducts to the knowledge of philosophical truth, and forms the mind to philosophical enlargement and accuracy of thought, more happily than almost any other species of investigation in which the human intellect can be employed."
TILLOCH.

"Tout homme qui reçoit une education libérale, compte aujourd'hui la chimie parmi les objets les plus indispensables de ses études."
FOURCROY.

Richard Taylor and Co. Printers, Shoe-lane,

TO

WILLIAM SMITH, Esq.

REPRESENTATIVE IN PARLIAMENT

FOR

THE CITY OF NORWICH,

&c. &c. &c.

Sir,

In presenting this work a second time to the Public, it would be superfluous to repeat my former expressions of esteem for the honour of your patronage.

Should the additions to this volume tend to confirm to me that general countenance and support which I have already experienced, or contribute, in any way, to the progress of *chemical science, I shall consider the time which I have devoted to the improvement of this edition, as not unprofitably employed.*

In the hope that you may long live to extend your protection to Science and the Arts, and continue to render mankind your debtors by unremitting exertions for the public weal, I remain, Sir, with every sentiment of gratitude, for this additional mark of your approbation,

your obedient humble servant,

SAMUEL PARKES.

London,
October 26, 1807.

PREFACE

TO THE

SECOND EDITION.

The very flattering reception which the "Chemical Catechism" has met with from the public, the whole of the first impression having sold rapidly, and the uniformly respectable character it received in the periodical reviews, have encouraged the author to prepare a second edition, which he now gives to the world with a confidence that he did not at first allow himself to entertain.

To render this edition still more acceptable to the public, much new matter has been added, particularly in the Notes; many striking experiments have been introduced; and every new discovery has been noticed, that was thought likely to interest the student.

Though the author might now, perhaps, be justified in omitting to state the motives that first induced him to engage in such an undertaking, it may nevertheless be observed, that, in considering the great importance of chemistry to the arts and manufactures, it occurred to him, that an initiatory book, in which simplicity was united with perspicuity, would be an acceptable present to a variety of persons, who have not had leisure or opportunity to study more elaborate treatises; and especially to those parents who are not qualified by previous acquirements, to instruct their children in the elements of this science, than which there can be nothing more essential, in whatever line of life they may be destined to move. As an attempt therefore to supply this desideratum, The Chemical Catechism was first prepared for the eye of the public,—the author having it, at the same time, in his contemplation to exhibit, in a popular form, a body of incontrovertible evidence of the wisdom and beneficence of the Deity, in the establishment and modification of those laws of matter which are infinitely and beautifully varied, and whose operation is too minute to be the object of general notice. For, if it could be proved, to the satisfaction of youth, that matter is subject to a vast variety of laws which escape common observance, and that in the adjustment of those laws, the utmost attention, if it may be so expressed, has been paid to our convenience and comfort,——such a detail, it was imagined, would tend to make a more indelible impression on the young mind, than the display of the same goodness in the operation of causes which come under our daily notice and observation.

With these views it naturally occurred to the author, that the work would be very incomplete, should he neglect to offer to the student some of those moral reflections which spontaneously arise in every contemplative mind, when considering the magnificent system of nature: and though such remarks may perhaps be regarded by some as irrelevant to chemical science, yet, to repeat the former apology, it may be observed, that, in compiling any initiatory book, no writer as a parent, could lose sight of the necessity of embracing every favourable opportunity of infusing such principles into the youthful mind, as might defend it against immorality, irreligion, and scepticism.

For the accommodation of schools, and to render the generality of parents and preceptors more competent to explain and expatiate upon the variety of facts which the science of chemistry presents, and to qualify them in some measure to afford such answers to a number of questions, which the young pupil, in proportion as he advances and becomes more interested in the experiments, will not fail to demand, the author has added a variety of explanatory notes. Many of these will be found to contain new matter, or, at least, what is not generally known or published; others, and perhaps the majority, were drawn from various sources: but as many were quoted from memory, and still more from the common-place-book of the compiler, he was compelled, in some instances, either to omit the authorities, or entirely forgo the advantages he had derived from the works, experiments, and opinions of some of the most enlightened chemical philosophers of the age. Here he has constantly been guided by one rule—to produce rather what is useful than original.

It may also be remarked, that the catechetical form which was first chosen for this work, has been found to possess at least all the advantages that any other mode of instructing youth in chemistry can claim; the work having already been introduced with advantage into several of the most eminent seminaries in the kingdom; and, that, if the author's original intention be followed, the progressive improvement of the student will be pleasant, rapid, and correct.

The author assuredly never expected that the answers should be committed to memory *verbatim* by the pupil; nor indeed, that the language of the questions should always be literally adhered to by the tutor; but merely that the whole should be clearly comprehended by the parent or tutor, which, with the assistance of the notes, is no difficult task; and then to allow the student to employ his *own language* to explain his ideas, and form the responses.

Thus this treatise, the author confidently hopes, possesses every requisite to render it a *first book* for the chemical student; and that, whether it be employed as a catechism, as a set of dialogues, as matter for familiar conversation, or as a book for the closet, still the original design—a correct initiation into the science of chemistry—will be the result; for if these rudiments of chemical knowledge have been drawn in such form as to invite the young to study larger and more extended works*, and prepare them to adopt that theory only which can be substantiated by their own experiments, the chief intention of the author will be then fully accomplished.

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* In compiling this elementary work, the author has endeavoured uniformly to direct the reader to the best treatises in each department of the science, with a view to facilitate a progressive improvement; and to render the "Chemical Catechism", a kind of text-book for the student.

CONTENTS.

FRONTISPIECE,

FROM AN

ETCHING ON GLASS,

By means of Fluoric Acid.

THAT great advantages would be obtained in the art of printing, if impressions could be taken from GLASS with the same facility and security as from copper, was first suggested to the author by Mr. Hume; and though the Frontispiece to the first edition of the "Chemical Catechism" was not a finished drawing, it served to show the practicability of this new mode of printing.

After many failures and disappointments, the great difficulty of guarding the pane of glass, so as to endure the rolling press, has been conquered; and the author flatters himself, that the plate, which accompanies this edition, will demonstrate what may be done by perseverance, and will also exhibit a very favourable specimen of the abilities of the artist, Mr. Mutlow, who had never before attempted any thing of the kind on *glass*.

Some useful articles of apparatus have been selected to fill the plate, so as to serve sufficiently the author's original purpose, viz. to give to the chemical student one complete example of the powers of Fluoric Acid.

FIG. 1. Represents a glass jar, inverted over the flame issuing from the combustion of hydrogen gas. In this case the oxygen of the atmosphere combines with the hydrogen, and water is formed, which will evidently appear attached to the inside of the jar. The undermost vessel is to contain a mixture of the filings of zinc or iron, with some sulphuric acid diluted with six times its weight of water, and a glass tube, or a piece of tobacco-pipe, thrust through a perforated cork, fixed into its neck.

Fig. 2. A glass funnel for pouring acids and other liquids, in a horizontal direction, into retorts and other vessels.

Fig. 3. A glass matrass. In a great variety of experiments nothing, however, answers better than a common oil-flask.

Fig. 4. Consists of a distilling apparatus. The retort and its receiver are placed each on its proper stand; the retort has an opening on its top with a stopper to fit; and its branch or mouth is inclined a little, so as to enter the receiver, to which it is to be luted.

Fig. 5. An Argand's lamp. This is placed immediately under the retort, and, though contrary to general practice, should always be separated, and not slide upon the stem of the retort-stand, in order that it may be readily trimmed, removed, lowered or raised, without disturbing the apparatus.

Fig. 6. A tubulated bottle. This is very commodious for several purposes, but principally to be connected by bent tubes to the tubulure of the receiver (Fig. 4.); so that by employing two or more of these, a Woulfe's apparatus may be formed.

Fig. 7. A refrigeratory, in which a metallic tube or worm is fixed, so that the vapours arising in distillations may pass into the tube at its upper end, and be condensed in their passage by the cold water, which surrounds this tube. A refrigeratory is generally made of wood or, particularly when small, of japanned tin.

Fig. 8. A small metallic still with its head or cover on. The pipe branching from the head is designed to fit into the upper part of the worm in the refrigeratory (Fig. 7.) where it is to be luted, to prevent the escape of any vapours till they arrive at, and drop into a proper receiver placed at the lower end of the worm.

Fig. 9. A gas bottle with its bent tube, which should be accurately fitted into the neck. This serves for the extemporaneous formation of elastic fluids, which, as they are evolved, pass through the tube, and may be readily conveyed through the water in a pneumatic trough (Fig. 13.), into an

inverted jar placed on the shelf for the purpose, having been first filled with water.

FIG. 10. A crucible; this is commonly made of some refractory earth, plumbago or metal, so as to endure intense degrees of heat.

FIG. 11. The bladder-receiver, described in a note, page 550. This may be furnished either with a metallic tube and stop-cock, as here represented; or fixed on a piece of common tobacco-pipe, which, if firmly inserted in the cork of the receiver, will often be sufficiently accurate.

FIG. 12. An alembic. The whole of this may be made either of glass, porcelain-clay, silver, or platina, though glass will be found to be the best. The head, with its stopper, is seen separated from the body, into which it is fitted and luted during an operation. The head is hollowed in such a way, that whatever condenses there and trickles down, must collect in the interior current and pass on through the spout into a receiver.

FIG. 13. The pneumatic trough, or tub, is here represented filled, and a jar placed on the shelf, as before described (see Fig. 9). This jar, for some purposes, may be close at the top, or, if open, the neck should be furnished with a glass-stopper or a stop-cock; thus, with a little management, any gas, collected in this jar, may be readily transferred into the bladder-receiver, (Fig. 11).

FIG. 14. A glass funnel of this description is extremely convenient, as, on account of the curvature in the stem, any acid or liquid may be affused upon other ingredients, while no vapour or gas is suffered to escape out of the vessel; and this, in many chemical processes, is often essentially requisite.

AN

ESSAY

ON

THE UTILITY OF CHEMISTRY

TO THE

ARTS AND MANUFACTURES.

Addressed to Parents in the higher and middle Ranks of Life.

FROM the present state of chemical knowledge, and the daily improvements which are making in our arts and manufactures by the judicious application of its principles, it is become absolutely necessary to make CHEMISTRY a part of the education of every one, whether he be designed to move in the higher ranks of life, or is likely to be concerned in any of the manufactures of the country.

I have therefore imagined that I should render an acceptable service to society by enumerating a few of the advantages which arise from the acquisition of this branch of knowledge; for, as a large proportion of the community is not apprised of its real value, that general attention to it which it deserves, can never be expected until its utility be demonstrated.

It would, however, be no difficult matter to show that the world might derive great advantages even from the diffusion of a *theoretical* knowledge of philosophy and chemistry. An instance or two will place this assertion in a clear point of view. Two thousand years ago Archimedes was ridiculed for his attention to mathematics and the abstruse sciences; yet by this knowledge he was enabled to invent such mechanical engines as were sufficient to resist the whole Roman army. And such a dread had the soldiers of this man's science, that if a rope only were let down from the walls of the city of Syracuse, the whole army would retire from before it in the utmost consternation.

A further proof of the importance of the dissemination of useful knowledge may be taken from the construction of the *Steam Engine*. Mr. Watt often acknowledged that his first ideas on this subject were acquired by his attendance on Dr. Black's *Chemical* Lectures, and from the consideration of his theory of latent heat and the expansibility of steam*.

The well informed people of France are so satisfied of the importance of chemical knowledge, that chemistry is already become an essential part of education in their public schools.—It shall be my business in this place to endeavour to demon-

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* Davy.

strate it to be of *equal* importance to the various classes of our countrymen, that the science should be cultivated with the same ardour in these kingdoms. The science we here recommend to your most serious attention, has for its objects *every substance* of the material world, and, therefore, is equally interesting to every civilized nation upon earth.

Is your son born to opulence,—is he the heir to an extensive domain; make him an analytical chemist, and you enable him to appreciate the *real* value of his estate, and to turn every acre of it to the best account. Has he a barren tract of country, which has been unproductive from generation to generation; he will explore its bowels with avidity for hidden treasures, and will probably not explore it in vain. By analysing the minerals which he discovers, he will ascertain with facility and exactness what proportion of metal they contain, and which of them may be worked to profit. Thus he will operate on sure grounds, and be prevented from engaging in expensive and unprofitable undertakings.

Chemistry will teach him also how to improve the *cultivated* parts of his estate; and, by transporting and transposing the different soils, how each may be rendered more productive. The analysis of the soils will be followed by that of the waters which rise upon, or flow through, them;

them; by which means he will discover those proper for irrigation; a practice the value of which is sufficiently known to every good agriculturist.

Should he *occupy* his own estate, and become the cultivator of his own land; he must of necessity be a chemist, before he can be an *œconomical* farmer. It will be his concern not only to analyse the soils on the different parts of his farm, but the peat, the marle, the lime, and the other manures must be subjected to experiment, before he can avail himself of the advantages which might be derived from them, or before he can be certain of producing any particular effect. The necessity of analysis to the farmer is evident from a knowledge of the circumstance, that some kind of lime is injurious to land, and would render land hitherto fertile actually sterile. Besides, a knowledge of the first principles of chemistry will teach him when to use lime *hot* from the kiln, and when *slacked*; how to promote the putrefactive process in his composts, and at what period to check it, so as to prevent the fertilizing particles becoming effete, and of little value. It will also teach him the difference in the properties of marle, lime, peat, dung, mud, ashes, alkaline salt, soap waste, sea water, &c., &c., and, consequently, which to prefer in all varieties of soil. A knowledge of the chemical properties

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of bodies will thus give a new character to the agriculturist, and render his employment rational and respectable*.

Are you a practitioner of MEDICINE, and have acquired great and deserved reputation in your profession,—if you are not a chemist, you must recollect many painful disappointments, and must have witnessed very unexpected results from the effects of medicine, when you have administered two or more powerful remedies in conjunction. A slight knowledge of chemistry would have informed you that many of the formulæ in the Pharmacopœia, which are salutary and efficacious, are rendered totally otherwise if given with certain other medicines,—not to say often destructive. Many instances of these chemical changes might be adduced, but one will suffice. Mercury and oxygenized muriatic acid have both been administered by medical men, and, *separately*, either of them may be taken without any injury to the animal œconomy; but if a physician, ignorant of the chemical operation of bodies on each other, should give these substances *in conjunction*, the most dreadful consequences might

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* Lavoisier cultivated 240 acres of land in La Vendée, on chemical principles, in order to set a good example to the farmers; and his mode of culture was attended with so much success, that he obtained a third more of crop than was obtained by the usual method, and in nine years his annual produce was doubled. Lalande's Life of Lavoisier.

ensue, as oxygenized muriate of mercury is a most corrosive poison.

If this profession be your son's choice, charge him, when he walks the hospitals, to pay particular attention to the Lectures on Chemistry, and to make himself master of the chemical affinities which subsist between the various articles of the Materia Medica*. This will inspire him with professional confidence; and he will be as sure of producing any particular chemical effect upon his patient, as he would if he were operating in his own laboratory. Besides, the human body is itself a laboratory, in which by the varied functions of secretion, absorption, &c., composition, and decomposition, are perpetually going on: how, therefore, can he expect to understand the animal œconomy, if he be unacquainted with the effects which certain causes chemically produce? Every inspiration we take, and every pulse that vibrates within us, effects a *chemical* change upon the animal fluids, the nature of which requires the acuteness of a profound chemist to perceive and understand. Neither can a physician comprehend the nature of the animal, vegetable, or mineral poisons without the aid of

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* Mr. Deyeux has shown that even the preparation of plasters may be much improved by chemistry. His ingenious paper in the 97th number of the Annales de Chimie contains much curious matter well worth the perusal of medical men.

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chemistry*. Many thousand lives have been lost by poison, which might have been saved had the physician been in possession of the knowledge which he may *now* acquire by a cultivation of chemical science. And though the operation of many of the poisons upon the system be in these days well understood, nothing but a knowledge of chemistry can enable the practitioner to administer such medicines as will counteract their baneful effects†.

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[*] All *animal* and *vegetable* poisons destroy by deoxidizing the blood. Substances which contain a large portion of oxygen are the real antidotes to *such* poisons. On the contrary, *metallic* poisons are baneful in consequence of the oxygen they contain. Metals are devoid of activity in a metallic state; but when converted into oxides they become poisonous and corrosive, according to the portion of oxygen combined with them. Thus the gray and the white oxides of mercury are only purgative or alterative; while the red oxide is a corrosive poison. Decoctions of bark, having a great affinity for oxygen, have been given to counteract an over dose of antimonial powder, and have produced the desired effect.

[†] The following fact will show the importance of chemical knowledge to every practitioner in medicine more forcibly than a thousand arguments. Having myself been instrumental in saving a valuable life, I feel great pleasure in relating the circumstance:—

About Christmas 1805 an apothecary in one of the northern counties having drunk some bottled porter, was seized with symptoms which convinced him that he was poisoned; but not knowing what noxious matter he had taken, and being incapable of analysing the remainder, no antidote could be applied, and he gave himself up as lost. A physician had been called in: but neither he nor the patient, nor his partner, could get any information by examining the remaining contents of the fatal bottle; though, I understand, they are all intelligent men, and in great reputation in their profession, If we look to the MANUFACTURES of the kingdom, there is scarcely one of any consequence that does not depend upon chemistry, for its establishment, its improvement, or for its successful and beneficial practice. In order to see the connexion which subsists between chemistry and the arts, it will be necessary to take a short view of the principal trades which are carried on in these kingdoms.

One of the staple manufactures of the country is that of IRON; and it will be found that, from the smelting of the ore to the conversion of it into steel, every operation is the effect of chemical affinities. In the first place, it requires no small share of chemical knowledge, to be able to

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sion. In this dilemma what could be done? At last one of them recollected that a neighbouring gentleman had the reputation of being a good chemist. To him the physician and the partner of the patient hastened, to get the dregs analysed, and to learn what ought to be administered. Fortunately, this gentleman had just received Göttlings' Book of Tests, which I had procured for his brother, and which had been sent to him but a very short time before. By this book he was enabled to ascertain that the poison was oxide of antimony: and when the patient was informed of it, he recollected that antimonial wine had been kept in a similar bottle some years before; and supposed that the porter must have been bottled without the dregs being properly washed out. When the nature of the poison was thus ascertained, the gentleman had no difficulty in directing the physician to a proper antidote, which was administered immediately; and the life of the unfortunate man was preserved; but, in consequnce of the time allowed to elapse previous to its exhibition, the poison had so far taken possession of the system as to deprive him of the use of a limb.

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appreciate the *value* of the different ores, and to erect such furnaces for their reduction as may be contrived in the best possible manner for facilitating their fusion, and for producing good pigs. The subsequent processes to convert the metal into malleable iron are entirely chemical, and will be conducted to the best advantage only by those who have acquired a knowledge of the chemical changes which take place in these operations. The making of CAST-STEEL, which has been kept so profound a secret, is now found to be a simple chemical process, and consists merely in imparting to the metal a portion of carbon, by means of fusing it in crucibles with carbonate of lime, or by cementation with charcoal powder, in a peculiar kind of furnace constructed for that particular purpose.

The manufacturers of *utensils, &c.* in cast iron (called IRON-FOUNDERS) will also acquire some valuable information by the study of chemistry; as it will teach them how to mix the different kinds of metals; how to apportion the carbonaceous and calcareous matter; and how to reduce the *old* metal, which they often receive in exchange; many hundred tons of which are annually sent away as ballast for ships, for want of that knowledge which would enable them to convert it into good saleable iron.

The WOOLLEN, the COTTON, and the CALICO manufactures are also become of great importance to these kingdoms. In order to preserve these sources of national wealth, the utmost attention must be paid to the beauty, the variety, and the durability of their several colours. Now of all the arts, none are more dependent upon chemistry than those of DYEING and CALICO PRINTING. Every process is chemical; and not a colour can be imparted, but in consequence of the affinity which subsists between the cloth and the dye, or the dye and the mordant which is employed as a bond of union between them. It is surely then evident how valuable a chemical education must be to that youth who is designed for either of these trades, and how necessary is that portion of knowledge which shall enable him in a scientific manner to analyse his different materials, and to determine the kind and the quantity necessary for each process. After all, his colours will be liable to vary, if he do not take into the account, and calculate upon, the changes which take place in them by the absorption of oxygen; a knowledge of which, and of the different degrees of oxidizement which the several dyes undergo, requires no small share of chemical skill: and yet this skill is absolutely necessary, to enable either the dyer or the calico printer to produce in all cases permanent colours of the shade which he intends. Moreover, these artists must be indebted to chemistry for any valuable knowledge which they may acquire of the *nature* of the

the articles they use in their several processes; not to say that they are wholly dependent upon this science for the artificial production of their most valuable mordants, and for some of their most beautiful and brilliant colours*.

The art of BLEACHING, which is so intimately connected with calico printing, has also received such improvement from the science of chemistry, that no man is now capable of conducting it to

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* An instance or two will render this evident. Formerly a calico printer required many weeks to produce a printed cotton with some colours such as an olive ground and yellow figures; a scarlet pattern on a black ground; or a brown ground with orange figures:—but, by means of chemical preparations, the whole of this work may now be done in a few days; patterns, more delicate than ever, may be produced; and all with a degree of certainty of which former manufacturers had no idea; the system being now entirely altered. According to the former practice, the mordant was first applied to those parts of the cloth that were intended to be olive, brown, or black; it was then necessary for the piece to remain some time before it could be dyed, and afterwards to be exposed in a bleaching ground a sufficient time to clear those places from the colouring matter of the dye which had not been acted upon by the mordant: a different mordant was then applied by the pencil; and it was necessary to pass the whole piece through the dyeing copper a second time, in order to give the desired colour to those particular parts and finish the pattern.

Now, all these effects are produced by dyeing the cloth a self colour in the first instance, and afterwards merely printing the pattern with a chemical preparation, which discharges a part of the original dye and leaves a new colour in its stead. Thus a brown may be changed in an instant to an orange; a dark olive to a yellow; or a black to a bright scarlet. In consequence of similar ~~these~~ improvements, rich chintz patterns, which formerly required two years or more to be completed, are now commonly finished in a few weeks.

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the best advantage, without a knowledge of the principles on which the present practice is established.

The manufactures of EARTHEN WARE and PORCELAIN, which were so much improved and extended by the ingenious and industrious Wedgwood, and which are become by his means a source of national wealth, and give employment to thousands of the community, are dependent upon chemistry for the successful management of all their branches, from the mixture of the materials which form the body of the ware, to the production of those brilliant colours which give a value to the manufactures by their permanency and beauty.

Mr. Wedgwood was so sensible of the importance of chemistry to these arts, that he not only applied to the study of the science himself, but, upon the death of the celebrated Dr. Lewis (author of the Commercium Philosophico-Technicum), actually engaged his assistant, a Mr. Chisolme, to experimentalize with him, and to devote *his whole attention* to the improvement of the manufacture by the application of his chemical knowledge, of which perhaps few men in the kingdom *at that time* had a larger share. A faint idea of the advantages which he derived from these sources may be conceived from the following circumstance:—Dr. Bancroft, in his "Philosophy of Permanent Colours," when treating

ing on iron, says, "I remember having been told by Mr. Wedgwood, that nearly all the fine diversified colours applied to his pottery were produced only by the oxides of this single metal." This one fact is sufficient to show with what assiduous application he must have studied chemical science, and how insufficient every attempt to bring his manufacture to the perfection which it has now attained, would have been, without this attention.

The sister art, that of making GLASS, is also entirely chemical, consisting in the fusion of siliceous earth with alkali and the oxides of lead. In this trade, as well as in many others, the chemical manufacturer, and the man of enlightened experience, will have many advantages. He will not only know how to analyse his alkalies and to ascertain their exact value before he purchases, but will be enabled on chemical principles to ascertain the exact quantity necessary for any fixed portion of silex, which to those who are ignorant of our science must always be a matter of uncertainty, and must repeatedly subject them to losses and disappointment.

The TANNING OF HIDES is a process which was formerly carried on by persons who merely followed a routine of operations, to which they had been accustomed, without knowing the real cause of any of the changes produced. It has now, however, been well ascertained, that the whole art consists in impregnating the animal matter with that peculiar principle taken from the vegetable kingdom, called *tan*, (or *tannin*) the effect of which may be explained entirely on chemical principles. It is also now known that many substances, besides oak bark, contain tan; and to chemistry we are indebted for the means of discovering with accuracy the *quantity* of tan which the several astringent vegetables contain. Besides, this principle having been formed *artificially* by a modern chemist, it is not improbable that, whenever these manufacturers pay a proper attention to the science we recommend, they may be able to direct us how to prepare for them, in our laboratories, the article in question, so as entirely to supersede the use of oak bark. This would be an event of great national importance, as the demand at present is so great, that it is not only imported from the continent, but trees, it is well known, have been actually cut down on purpose for the bark. Should the chemical tanner not be fortunate enough to make a discovery of the kind just mentioned, he will at least be able to analyse the substances now in use, and to appreciate their *relative* value; a matter of no small moment to a man who operates upon a large scale. Chemistry will enable him also to combine the tanning principle with the skins, so as to form leather the most impervious to moisture; and to give the hides the greatest increase of weight in the least possible time:—and these are the main secrets on which the profit of the trade chiefly depends.

The manufacturers of MOROCCO LEATHER, an article entirely new in the productions of this country, have the utmost reason to regret the want of chemical knowledge. Till within these few years, the consumers of morocco depended entirely on a foreign supply, many fruitless attempts having been made to prepare the article in this country. Later trials, with various chemical mordants, have, however, so far succeeded, that several manufactories have been established in the metropolis, where the most beautiful moroccos are now prepared at prices which have superseded the necessity of all foreign importation. Notwithstanding this, some colours are still produced by these manufacturers in a tedious and expensive way:—a series of well conducted and appropriate chemical experiments would no doubt direct them to prepare the same colours, with greater certainty, and by a more œconomical process.

The manufacture of SOAP, an art of considerable importance, and which materially aids the revenue of the country, has in general been conducted, like many of the foregoing, without any regard to system: and yet, perhaps, there is no manufacture which can be benefited in such various ways by chemistry as this. To those who are designed for this trade I have no hesitation in recommending the study of the science as a matter of the first importance. Many thousands per annum, now lost to the community, would be saved, if the trade were in general carried on upon scientific principles. Make a soap-boiler a good chemist, and you teach him how to analyse barilla, kelp, potass, &c., so as to ascertain the proportion of alkali in each,—the only sure guide to purchasing with advantage and profit, which with the common manufacturer is mere chance. When these articles are at an exorbitant price, he will have recourse to various residuums, which he will decompose by *chemical* means, and make use of as substitutes. He will learn, in choosing his tallows, how to avoid those which contain a large portion of sebacic acid, which require much *more* barilla than good tallow, and yet produce *less* soap. He will know how to oxidize the common oils and oil dregs, so as to give them consistence, and render them good *substitutes* for tallow,—and how to apportion his lime so as to make his alkali perfectly caustic, without using an unnecessary quantity of that article. He will be aware of the advantage to be derived from oxidizing the soap while boiling. A knowledge of the chemical affinities will teach him how, at a cheap rate, to make as good and as firm soap with *potass,* as with the mineral alkali; and how to take up the heterogeneous salts, so as to give the alkali full opportunity of forming a chemical combination with the oils, tallows, &c. And, lastly, he will know how to make use of the *waste* lyes so as to decompose the salts which they contain, and convert them to good and serviceable alkali, fit for future operations*.

The manufacture of CANDLES, which is frequently connected with the foregoing, though it is of comparatively small importance, may yet derive advantages from chemistry, which would repay the study. Foreign tallows, which frequently contain a large portion of acid, rendering them inferior to the English, may be purified at the most insignificant expense by chemical means; and by the proper application of chemical agents, other brown tallows may be rendered beautifully white, and fit for the best purposes.

Where great quantities of candles are used, as in large manufactories, mines, collieries, &c., a great saving would arise from the use of carbureted hydrogen gas, which produces a beautiful intense light, much more cleanly than oil or tallow, and at little or no expense. A slight knowledge of the mode of managing the gases, would enable the proprietor of collieries to procure this gas from the small coal, which is *trodden under-foot,*

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* Manufacturers of soap, in general, avail themselves of none of these advantages.

foot, and to light up his coal pits with it with the greatest safety, and at no EXPENSE. If this mode were adopted, the workmen would be lighted *much better* than they can possibly be by any other means; thousands of pounds would be annually saved to the community; and the many tons of tallow, which are now consuming in these subterranean works, might be used in the manufacture of soap; which would tend to lower the price of that necessary article, and render our poor more wholesome and comfortable.

The BREWING OF FERMENTED LIQUORS, which is a trade of considerable consequence in the metropolis, is altogether a chemical process. To those persons, whose concerns are so large that it would require a princely fortune to purchase even the *utensils*, it must surely be of the utmost importance to acquire some knowledge of the *principles* of bodies, and of the nature of those changes which take place in the materials upon which they operate. I would therefore say to such persons, Give your sons a chemical education, and you will fit them for conducting, in the best possible manner, the business which you have established. Hence they will learn how the barley, in the first instance, is converted to a *saccharine* substance by malting*; how the fer-

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* There is a valuable paper on malting in the fifth vol. of the Memoirs of the Manchester Society, by Mr. Joseph Collier.

mentative process converts the saccharine to a *spirituous* substance; and how the latter, by a continuation of the process, becomes changed into *vinegar*. The nature of fermentation (which till lately was entirely unknown) will be studied and understood; and they will not only have learnt the means of promoting and encouraging this process, but how to retard and check it, whenever it is likely to be carried too far; so that the scientific brewer will be as sure of uniformly obtaining satisfactory results, as he would if he were operating on matter by mere mechanical means.

In like manner the DISTILLER, the maker of SWEET WINES, and the VINEGAR MANUFACTURER, will all receive benefit from the cultivation of the science we are recommending. Till the promulgation of the new chemical doctrines, the making of vinegar was carried on like many other trades, in which the makers themselves had no idea of the nature of their own process. An acquaintance with chemistry will teach them many important matters; particularly, how it is that the spirituous fermentation is succeeded by the acetous; and how the liquor acquires the substance necessary to produce this change. When this is once known, they will soon find by experiment how to oxygenize their wash at the least expense, and in the least possible time. Indeed, when chemical knowledge is more advanced, the process which now takes several months will probably be completed in as many days.

The REFINING OF SUGAR is also a chemical process; every branch of which depends upon laws well known to chemists. The separation of the sugar from the molasses; the absorption of the superabundant acid; the granulation of the purified sugar; and the crystallization of candy; will all be conducted most œconomically, and with the least difficulty, by those who have studied the science with a view to the improvement of their art.

The REFINING OF GOLD AND SILVER may appear to be merely a mechanical operation; but even in this trade the artist cannot produce a single effect which is not attributable to the play of the chemical affinities. Besides, there is great reason to believe that a considerable portion of silver is often lost in the process which succeeds that of *quartation*, by the blue water being removed to the verditer-vats before the whole of the silver has been precipitated. A knowledge of chemical principles would suggest to the refiner a mode by which, without the aid of any apparatus, he might in an instant detect even a tenth of a grain of that metal, if left in the solution.

The manufacturers of ALUM, of COPPERAS, of BLUE VITRIOL, and of all other SALTS, would likewise do well to become chemists, before they attempt to bring their several arts to the perfection of which they are capable. The crystallization of salts depends upon so many adventitious circumstances, that no small share of knowledge is necessary to enable a manufacturer at all times, and in all seasons, to produce the article he intends. Till lately the MAKERS OF ALUM bought alkalies of every description. An accurate analysis of alum has now discovered, that potass and ammonia are the only alkalies which enter into the composition of alum; and consequently, that during a series of years large sums have been expended by the manufacturer for an article of no use.

Even science itself is now reaping the benefit of its own discoveries. A few years ago, the MANUFACTURERS OF PAPER were apprehensive that it would be impossible to supply a quantity of that article fit for printing upon, adequate to the increasing demand. Necessity however, often the source of new inventions, had recourse to chemistry; and in this science, of universal application, found the means of improving the colour of the very coarsest materials—so that rags which formerly would have been thrown by for paper of the lowest description, are now rendered subservient to the progress of truth, and the promulgation of knowledge. And so easy is the application, that an immense quantity of the materials can be prepared in a few hours; and paper sufficient to print a copy of largest work in the English language may thus be whitened at the expense of only a few pence. These improvements, which, however, are not yet universally practised, will, when chemical science is better understood, probably lead the way to a cheap method of bleaching *coloured* rags also, and enable the bookseller to furnish us with the most common works in a style of neatness to which we have not hitherto been accustomed.

In like manner it might be shown that the making of BREAD, SUGAR, STARCH, VARNISH, and OIL OF VITRIOL, the REFINING OF SALTPETRE, and the MANUFACTURES OF PRUSSIAN BLUE, CUDBEAR, ARCHILL and other colours, are all dependant upon chemistry for their improvement and successful practice:—but I flatter myself that the examples already adduced are sufficient to show that chemistry is now a necessary branch of the education of youth. Even the management of a GARDEN may receive improvement from a cultivation of this science, as it explains the growth of vegetables, shows the use of the different manures, and directs the proper application of them*.

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* Natural history is intimately *connected* with chemistry, as it must depend upon this science for any elucidation of the minute properties of those substances, the outward characters of which it describes; so that what Mr. Dayes has said of the painter, may with

The various operations of Nature[*], and the changes which take place in the several substances around us, are so much better understood by an attention to the laws of chemistry, that in every walk of life the chemist has a manifest advantage over his illiterate neighbour. And it may be remarked, that in case of failure or disappointment in any particular line of commercial manufacture, the scientific chemist has resources as various as the productions of the country in which he lives, to which the uneducated man has no access.

Were parents aware of this truth, that sordid maxim *primo vivere, deinde philosophari*, would not be heard: but every youth would be instructed in the first principles of natural philosophy and chemistry, as the means of qualifying him for conducting with advantage the concerns with which he might be intrusted. If "knowledge is power," surely the *love* of knowledge, and a taste for accurate investigation, is the most likely way for conducting to opulence, respectability, and rational enjoyment.

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with greater truth be said of the chemist. "The volume of NATURE is laid open to him: his attention is directed to the vast and to the minute; and his imagination clings to perfection with ineffable delight."

[*] "Man should observe all the workmanship and the particular workings of Nature, and meditate which of these may be transferred to the arts."

Lord Bacon's Advancement of Learning, book v. 148.

Moreover, it is the necessary consequence of an attention to this science, that it gives the habit of *investigation,* and lays the foundation of an ardent and inquiring mind. If a youth has been taught to receive nothing as true, but what is the result of *experiment,* he will be in little danger of ever being led away by the insidious arts of sophistry, or of having his mind bewildered by fanaticism or superstition. The knowlege of *facts* is what he has been taught to esteem; and no reasoning, however specious, will ever induce him to receive as true what appears incongruous, or cannot be recommended by demonstration or analogy.

CHEMICAL CATECHISM*.

CHAP. I.

INTRODUCTORY AND MISCELLANEOUS.

What is Chemistry?

Chemistry[†] is the science which enables us to discover the peculiar properties of all natural bodies, either in their simple or compound state[‡].

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[*] *The pupil is advised to go through the catechetical part of each chapter before he attends to the notes; for, as the questions generally arise out of the preceding answers, the connection of the whole will be best perceived, and more likely to be remembered, by this method.*

[†] The following definitions of chemistry have been given by some of our best chemists. That in the text was chosen on account of its plainness, and because it was sufficiently concise to be committed to memory.

"Chemistry is the study of the effects of heat and mixture, with the view of discovering their general and subordinate laws, and of improving the useful arts."—Dr. Black's Lect. vol. 1. 12.

"Chemistry is that science which treats of those events or changes in natural bodies which are not accompanied by *sensible* motions."—Dr. Thomson, vol. 1. 3.

"Chemistry is a science by which we become acquainted with the intimate and reciprocal action of all the bodies in nature upon each other."—Fourcroy's General System of Chemical Knowledge.

[‡] The basis of chemical science is the analytical examination of the works of nature, and the investigation of the pro-

How do chemists examine the properties of bodies?

The chemical examination of bodies is in general effected by producing a change* in the *nature* or *state* of the body under examination†.

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perties and uses of the several substances with which we are acquainted: it should therefore be the first concern of every chemical student to receive nothing as true but what has actually been proved by experiment or analogy. Let him rely upon nothing but facts, and he will be in little danger of forming extravagant or erroneous opinions. If we "dare to investigate Nature, we must *see* her and *try* her on all sides, and be *sure* that she still confesses the same thing."

* This change is frequently effected by the addition of some *other* substance which forms a combination with a part of the substance under examination, and leaves the other part in a detached state. On this principle re-agents, or chemical tests, are employed, the operation of which will be explained as we proceed.

† To the eye, many substances appear similar to other substances, though they possess different, and perhaps opposite, qualities; it therefore became necessary to discover the means of analysing these substances, and of ascertaining wherein their difference consists. This we find in *chemical re-agents.*

It may, with few exceptions, be considered as an axiom in the science of which we are treating, that *whenever chemical action takes place, a real change is produced in the substance operated upon, and that its identity is destroyed.* An example will place this in a clear point of view. If a little powdered chalk (carbonate of lime) be put into a glass of water, the chalk will sink to the bottom of the vessel. Though it should be mixed with the water, if left at rest it will soon subside. No chemical action has taken place; therefore the water and the carbonate of lime both remain unaltered. But if a small quantity of diluted sulphuric acid be added to a glass of chalk and

By what means do chemists effect a change in the qualities or states of natural bodies?

It is generally effected by means of *heat**, or by the *mixture*† of some other matter with the matter intended to be examined‡.

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water, a violent effervescence will commence the moment they come into contact with each other; a chemical union of the two substances will be the consequence of this chemical action; the identity of each substance will be destroyed; and sulphate of lime (a body entirely different to either of the substances employed) will be produced.

* Heat has a tendency to separate the particles of all bodies from each other. Hence nothing more is necessary to effect the decomposition of many bodies than to apply heat, and collect the substances which are separated by that means. The mixture of two or more compounds often produces a decomposition in each by means of chemical affinity, a property of bodies which will be more fully explained hereafter.

† It is owing to the laws of affinity that we are enabled to examine natural bodies by means of *re-agents,* or chemical tests. Some of these are simple, and act by *single* affinity; others, which are compound, act by producing a *double* decomposition.—See chap. xiii.

‡ Some idea of this mode of examination may be given by the following experiment:—Put a small piece of solid camphor into a phial half filled with spirits of wine; in a short time the camphor will be dissolved in the fluid, and the spirit will be as transparent as at first. This solution is owing to the affinity which subsists between these two substances. If water be now added (which has a greater affinity for the spirit than the camphor has) the water will unite with the spirit, and the camphor will be precipitated. In this way, the camphor may be nearly all recovered, as at first. By distillation the

How does the application of heat and mixture enable chemists to examine the properties of bodies?

By these means chemists effect the *decomposition* of a compound body, and thus acquire a knowledge of the nature of its ingredients*.

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water may also be separated from the spirit, and exhibited in a separate state.

* This is called analysis. It is distinguished by chemists into the *simple* and the *complicated* analysis. The former is effected whenever a body is so decomposed that its elements may be exhibited in a separate state, and by reuniting them the body may be reproduced. Where the elements of a body form new compounds during its decomposition, and cannot be reunited to reproduce a similar substance to that which has been operated upon, it is an instance of *complicated* analysis.

In order to ascertain the exact nature of bodies, chemists have recourse to *synthesis* as well as analysis. Whenever the component parts of any body are reunited in order to form a similar substance, and a similar substance is actually produced, the nature of that body is said to be proved by synthesis. When a body admits of being examined in both these ways, the result is very satisfactory.

The examination of those substances which we receive from the hand of nature, if conducted on these principles, may sometimes be tedious, but the consequences will be pleasing; the processes may be slow, but they will be sure; and the acquisition of truth, by patient investigation, and by means of our own exertion, affords to a cultivated mind the most delightful gratification.

"Nature exhaustless still, has power to warm,
And ev'ry change presents a novel charm."

What is meant by decomposition?

In chemical language, decomposition means the act of dividing a body into its simple elements*. Thus water may be decomposed, and reduced into oxygen and hydrogen, which are simple substances, incapable of further decomposition.

What are the different states of natural bodies?

All bodies are either solid†, liquid, or aëriform.

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* Take sulphate of magnesia (Epsom salt) as an instance of the decomposition and re-formation of a substance by chemical means. Make a solution of this salt in boiling water, and pour into it a little of a solution of carbonate of soda; the soda will precipitate a white powder, which on examination will be found to be carbonate of magnesia. When settled, decant the supernatant liquor, evaporate it till a pellicle rises on its surface, and set it aside to crystallize. When cold, crystals of sulphate of soda (Glauber's salt) will be found in the vessel. In this decomposition, the sulphuric acid of the Epsom salt combines with the soda to form sulphate of soda, and the carbonic acid of the soda combines with the magnesia to form carbonate of magnesia. In this way Epsom salt may be analysed, and proved to consist of sulphuric acid and magnesia. In order to prove the composition of this salt by synthesis, dissolve magnesia in diluted sulphuric acid, saturate the liquor, and crystallize. Epsom salt will be the result.

It may be remarked, that chemists have not only the power of decomposing natural bodies, but of producing by combinations various other substances, such as are not presented to us by the hand of Nature. Alcohol and ether are of this class.

† When attraction prevails in bodies, they become solid; when caloric prevails, they become gas: fluidity seems to be a

What do you mean by a solid body?

Solidity is that quality of bodies whereby their parts cohere firmly*, so as to resist impression†.

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medium between the two. The ultimate particles of matter existing in these separate states escape the cognizance of our senses. They are so infinitely small, as not only to escape the scrutiny of the highest magnifying powers in glasses, but even imagination itself is incapable of forming any idea of the size of an original particle of matter. When we have reduced matter to the most impalpable powder, we are far, very far, from the *atoms* which compose that powder.

A new theory to account for the phænomena of matter has been proposed by the celebrated Boscovich, and admitted by many philosophers. An account of this system may be seen in the Supplement to the Encyclopædia Britannica, under the article *Boscovich*.

[*] The force of cohesion increases in a substance in proportion as its moleculæ are brought nearer together. Thus alumine, which has shrunk considerably in bulk by being submitted to a high degree of heat, has not only experienced much mechanical cohesion, but has thereby acquired the power of resisting acids and alkalies.—Berthollet's Chemical Statics, vol. 1. 3.

[†] Sir Isaac Newton has said, that the primary particles of all bodies are *hard*, whether solid or fluid; and that if the particles be so disposed or fitted to each other as to touch in large surfaces, such body will be hard; otherwise it will be soft. Perhaps it would be more philosophical to say, that when the attraction of aggregation is strong enough to resist the motion of the particles of a body among themselves, that body will be solid, otherwise it will be soft.

Mr. Lavoisier has explained solidity thus:—" The particles of all bodies (says he) may be considered as subject to the action of two opposite powers, repulsion and attraction, between

What are liquid substances?

Liquid substances are those whose parts do not cohere firmly, but have free motion among themselves*.

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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 cohesion they before had with each other, and the body ceases to be solid."

* We have no reason to suppose that fluidity is an essential property of any liquid substance whatever; but rather that solidity is the natural state of all bodies, for we are able to reduce most substances to a state of fluidity by the combination of caloric. In general, bodies treated in this way expand in all their dimensions, and the attraction of aggregation is so much weakened thereby, that the particles of the body slide over each other, and are put in motion by the slightest impulse. This is the only distinguishing character of fluidity that we are acquainted with.

On the contrary, the greatest number of liquid substances take a *solid* form by reduction of temperature. Thus water congeals, and forms ice. Even the gases show this disposition. The oxygenized muriatic acid gas becomes concrete, and crystallizes at a temperature near to that at which water congeals. All the gaseous substances, when they have lost their elasticity by forming some combination, are disposed to assume the solid state, if the temperature allows it. Ammoniacal gas and carbonic acid gas become solid as soon as they enter into combination; and hydrogen gas, the most subtle of the ponderable elastic fluids, forms, with oxygen gas, the water which becomes ice. See more on this subject in the 1st vol. of Berthollet's Chemical Statics.

What occasions the difference in these bodies?

Liquid substances are nothing more than solids converted into liquids by heat[*], a certain increase of which would convert the liquids into vapour.

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[*] Fluidity is owing to the matter of heat being interposed between the particles of the fluid; which heat would dissipate all fluids into the air, were it not for the pressure of the atmosphere, and the mutual attraction which subsists between those particles. Were it not for this atmospheric pressure, water would not be known in any other states than those of ice and vapour; for, as soon as ice had acquired caloric enough to give it fluidity, it would ~~begin to boil~~ evaporate, and would be dispersed into the regions of space. This may be proved by direct experiment, as will be shown in the following chapter. The constitution of the world in this respect exhibits a beautiful instance of the harmony of nature, and of the exquisite contrivance of its divine Author.

On the other hand, could we *totally* abstract the matter of heat from any fluid, no doubt but that fluid would by that mean be changed to a solid; the lightest vapours being nothing more than solids combined with heat.

Not only fluids, but all those substances which are soft and ductile, owe these properties to the chemical combination of caloric. Metals owe their malleability and ductility to the same cause; for, in very intense artificial colds, the most ductile metals, such as gold, silver and lead, lose their malleability and become brittle, as Van Mons has shown, Annales de Chimie, t. 29. 300.

The following experiment will *prove* that it is caloric which converts solids to fluids:—Expose a pound of water and a pound of ice, both at 32°, in a room the temperature of which is above the freezing point. The water will arrive at the temperature of the room several hours before the ice is melted. The caloric, therefore, which has all the time been entering

What other name is given to liquids?

They are likewise called fluids: we call the air also a fluid*.

Why is the air called a fluid?

Because it flows like a fluid†, and light substances will swim in it.

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into the ice, but is not to be found in it by the thermometer, must have become *chemically* combined with it in order to give it fluidity. The caloric appears to be lost; its properties are merged in the fluid, just as muriatic acid, by union with lime, loses all its characteristic properties.—See this further explained in the chapter on caloric.

* Atmospheric air is one of the permanently elastic fluids. Steam is an elastic fluid, but atmospheric air in all states, and in all seasons, is *permanently* elastic. This elasticity arises from caloric being chemically combined with the solid substances of which it is composed. I say *solid,* because we have abundant evidence that oxygen and nitrogen are both capable of taking a solid form, and actually do, in many instances, exist in a state of solidity. Nitrogen is a component part of all animal substances, and exists in a solid state in all the ammoniacal salts. Oxygen takes the same state when it combines with metals and other combustibles; and in the composition of the nitrous salts they both take the same state of solidity. These facts surely evince that atmospheric air owes its fluidity to caloric.

One of the general laws discovered by Dr. Black, and which he laid down as a chemical axiom, was, that "whenever a body *changes* its state, it either combines with caloric, or separates from caloric." The great number of natural appearances which are explained by this general law renders it important, and it ought to be remembered by all who wish to make a progress in the science.

† The air is also known to be a fluid, by the easy conveyance which it affords to sound.

What is the cause of bodies swimming in fluids?

All substances will swim if they be lighter than the fluids they swim in*.

Is this universally the case?

Yes; this is an established law of nature†. Thus a cork swims upon water, while a stone sinks in it.

In chemical laboratories a vacuum is often formed in the retorts and other glass vessels, which occasions frequent explosions, and sometimes dreadful accidents. These are produced by a torrent of atmospheric air rushing into these vessels. If the air did not possess the common properties of fluids, these effects could not take place. It is a property of fluids to press in all directions, upwards as well as downwards; so does atmospheric air.

* This may be shown to a child at the breakfast table, by placing a tea-cup upon a bason of water, and informing him that it swims there because it is specifically lighter than a body of water of its own bulk. Water may then be gradually poured from the tea-pot into the cup; and he may be directed to observe how the cup sinks in the bason as it becomes loaded with water, until the united weights of the water and the cup are too great for the water in the bason to support, and the whole sinks.

† Here the pupil may be informed that it is on this principle that ships and other vessels are constructed, and that it is this property of fluids which enables us to float a vessel from one country to another.

> "Along the glassy plane serene she glides,
> While azure radiance trembles on her sides."
>
> FALCONER.

The weight of goods in a vessel is indicated by the depth to which the vessel sinks in the water. In canal boats this is

Have you a clear idea of the cause of these substances sinking and swimming in fluids?

The first swims because it is *lighter*, and the other sinks, being *heavier* than water.

What do you really mean when you say that a stone is heavier than water?*

Not that the stone is heavier† than the *whole*

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shown by graduated brass plates affixed to the sides. An account of a curious method of ascertaining the tonnage of ships hydrostatically, may be seen in the first number of the Retrospect. It is founded on the different draught which a ship will have in salt and in fresh water, owing to the different specific gravity of the two fluids. That nautical men should be acquainted with this hydrostatical axiom, is certainly of importance; for, should a captain load his vessel with a *full* cargo at any sea port, his vessel would inevitably sink when brought into the Thames.

* Some of the questions in this introductory chapter may perhaps be thought trifling and insignificant; but the reader is requested to consider nothing unimportant that tends to lay a just and stable foundation for the superstructure of an interesting science. The generality of elementary writers presume too much when they suppose that what they omit is universally known. Many things which they consider to be of public notoriety, are known perhaps to few who have not paid a particular attention to the subject. Hence, many works which are called elementary disappoint the expectation of the student, and are laid by with distaste, for want of the first rudiments of the science being detailed with minuteness and simplicity.

† The pupil should be informed that *all* stones are not heavier than water, for that these natural bodies differ very much in specific gravity; that, though the specific gravity of sulphate of barytes is 4.40, or nearly $4\frac{1}{2}$ times as heavy as an

of the water in the vessel; for, if it be heavier than a portion of water of its own bulk, it must sink*.

What term is made use of to express the relative *weight of bodies?*

Specific gravity. Thus the specific gravity of one body may be much greater than that of another, though their absolute weights be the same†.

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equal bulk of water, some species of the asbestus are lighter than water. Some kinds of pumice stone are also much lighter than that fluid.

* It is an axiom in hydrostatics, that every substance which *swims* on water, displaces so much of the water as is exactly equal to its own *weight*; whereas, when a substance *sinks* in water, it displaces water equal to its bulk.

Take a piece of hard wood, balance it accurately in a pair of scales with water, and then place it gently on the surface of water in a vessel exactly filled with that fluid, and it will displace a portion of the water, which will flow over the top of the vessel. If the wood be now taken out with care, it will be found that the water in the scale will exactly fill the vacancy left by the wood.

† The specific gravity of bodies is denoted in chemical writings by comparing it with the specific gravity of pure water, in decimal figures, water being always considered as 1.000. Thus the specific gravity of the strongest sulphuric acid of commerce is said to be 1.900, or nine-tenths heavier than water. Iron is 7.650, or more than 7½ times heavier than water; that is, a cubic inch of iron, if put in a scale, would require 7½ inches of water to balance it; silver is 10.478; gold, 19.300; and platinum 23.000, or 23 times heavier than water. The specific gravity of bodies is noted in the same way throughout this work.

How do you explain or account for the difference in the specific gravity of different bodies?

When one body is larger, or takes up more room, than another of the same weight, the first is said to be *specifically* lighter*.

What definition do you give of the air which you spoke of in connection with this subject?

The air is that very light fluid, which surrounds†

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* The nations of antiquity were unacquainted with any method of ascertaining the specific gravity of bodies. A singular event was the cause of its being discovered by Archimedes 200 years before Christ. Having reason to believe that an unprincipled goldsmith had greatly debased the golden crown of Hiero II., king of Syracuse, he was anxious to ascertain the fact; but was perplexed by not knowing how to effect it. However, one day while bathing, the difference in the weight of his own body, when in the water and when out of it, gave him the idea that he might adopt *that* method for discovering the specific gravity of the king's crown; and it is related of him that he was so rejoiced at the discovery, that he leaped from the bath in an ecstasy, and ran naked about the streets of Syracuse, crying *I have found it! I have found it!* It would be a pleasing, and not altogether an unprofitable employment, to endeavour to recount the mathematical, philosophical, and chemical truths, that we are in possession of, which tend to promote the happiness and civilization of man, and which the ancients were unacquainted with. In these enlightened times every youth may find avocations suited to his taste, and even in his pleasures will be at no loss to select amusements which are both rational and respectable.

† If the earth had no atmosphere at the time of its formation, a chemist would have no difficulty in conceiving how an atmosphere might be produced by the decomposition of water and

us every where; it is the medium in which we live, and without which we could not exist*.

What is the great body of this fluid called?

It is called the atmosphere†.

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other substances, and that this might be effected by the agency of internal fires. I refer the reader desirous of investigating this subject, to an interesting essay in the second chapter of Lavoisier's Chemical Elements.

* The Creator knew how necessary atmospheric air would be for the support of animal life; he has accordingly endowed it with the property of preserving its own equilibrium at all times, and in all places. Its elasticity is such, that however it may be consumed by respiration or combustion, its place is immediately supplied with a new portion; and though by a mistaken policy the doors and windows of our habitations may be constructed so as to exclude it as much as possible, it *will* have admission; it forces its way through every crevice, and performs the important office assigned it, in defiance of all our exertions. If the properties which are given to the different substances in nature, and the laws by which they are governed, be thus examined, we shall find them all tending to one point, viz. the welfare and felicity of every species of animated beings.

† This word is derived from the Greek language, and signifies a body of vapour in a spherical form. By this name we understand the entire mass of the air which encircles all parts of the terrestrial globe, which moves with it round the sun, which touches it in all its parts, ascending to the tops of its mountains, penetrating into its cavities, and incessantly floating on its waters. It is the fluid which we inhale from the first to the last moment of our existence. Fourcroy, vol. i. 207.

The blue colour of the sky is owing to the vapours which are perpetually rising from the earth and mixing with the air. This Saussure demonstrated by experiment on the Alps.

You say the atmosphere is fluid; what proof have you of its being so?

Many instances might be adduced to show that the atmosphere is fluid, but the ascension of an air balloon is a sufficient proof of its fluidity*.

How do you account for an air balloon floating in the atmosphere† *?*

Because the whole when inflated with gas is

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* Atmospheric air, like all other elastic fluids, yields to the slightest impulse, and is put in motion with the greatest ease; but it has not the power of penetrating many substances, like oils and some other fluids.

The facility and rapidity of the motions of atmospheric air cannot be explained on any principle but its fluidity. Some of the winds move nearly at the rate of 4000 feet in a minute.

† This and the following question may appear to be an useless repetition of the doctrine taught in the first part of this chapter; but as innumerable facts dependent on specific gravity are perpetually occurring in every department of chemistry, it was thought advisable thus to *vary* the questions, in order to prevent a possibility of a young person committing this chapter to memory without thoroughly understanding what is so important to his future progress.

It is absolutely necessary for him to understand the nature of specific gravity, to enable him to analyse minerals, to examine the gases, and to perform a variety of other operations in chemistry. Besides, this knowledge will be of use in the common occurrences of life, and no one, who wishes to have a general acquaintance with things, ought to neglect to learn the methods of taking the specific gravity of bodies. For instance: suppose a person has a piece of silver plate which he suspects is alloyed more than it ought to be, a knowledge of specific gravity, and of the principle of bodies which sink in fluids, displacing so specifically lighter than an equal bulk of common air.

We have seen that cork swims on water, why does it not swim in air?*

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much of the fluid as is equal to their bulk, will enable him to ascertain its value with accuracy. He has only to weigh it in air and then in water, and calculate from the difference in its weight when weighed in these two mediums. Thus, if it weighs 46 ounces in air, and only 41½ ounces when weighed in water, its bulk of water is 4½ ounces. Now if 46 be divided by 4½, the quotient will be 10¼; which shows that the piece of plate is 10¼ times as heavy as its bulk of water, which is about the specific gravity of standard silver. *Pure* silver is 10½ times the specific gravity of water. For an account of the different methods of taking the specific gravity of different substances, see Additional Notes, No. 1.

* Poplar is the *lightest* wood we have next to cork, the specific gravity of which, according to Lavoisier, is .3830; but the specific gravity of cork is only .2400, water being 1.000.

Cork is the outward bark of a tree which grows wild in the southern parts of Europe. When the tree is of a certain age it may be barked annually for eight years. It is heated and singed over a strong fire, and then placed under stones in order to be pressed straight. According to Pliny, cork was known to the Romans, and was applied by them to as many purposes as it is at present. Xenophon relates that the Roman ladies who wished to appear tall placed several layers of cork within their shoes. Beckmann's History of Inventions, vol. ii. 115.

Cork possesses very singular properties. It may be easily compressed, but recovers its elasticity as soon as the compressing power is removed, and therefore fills up every crevice of that space into which it has been driven by force. It may easily be cut into any form; and though it abounds in pores, which

Because the cork is specifically heavier than the air, though lighter than water*.

What is the specific gravity of atmospheric air?

A pint measure of atmospheric air weighs only

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is the cause of its lightness, it suffers neither water nor any common fluid to escape through it.

The use of cork in preserving liquors is well known. Its use in making safety jackets for the preservation of lives by sea may be explained, also its use in teaching the art of swimming. The epidermis of all vegetables is of the same nature as cork.

* That one substance swims upon another in consequence of the superior density of the fluid which supports it, should be made very clear to the apprehension of the pupil; for, till he thoroughly understands this principle, it will be impossible for him to comprehend the cause of a variety of effects which will take place during the course of his experiments. When this is understood, it may be proper to point out some of the advantages which we derive from this property of fluids. That owing to this principle, the oxygen gas which is secreted by vegetables is detained in the *lower* regions of the air, that it may combine with the nitrogen gas produced by animal respiration, to preserve the purity of the atmosphere;—that owing to this, the carbonic acid gas, which is still heavier, and which is formed also by animal respiration and combustion, is confined within the reach of vegetables, which absorb it with avidity, and separate it into its original elements;—and that to this principle it is also attributable that the mephitic air, arising from the crowded haunts of men, does not produce pestilence, but mounts above the clouds to await fresh combinations, by means which nature has appointed to render it again useful and salubrious. One great use of *lightning* may perhaps be to promote the union of this nitrogen with the oxygen of the water which is held in solution in atmospheric air. That the Deity has established some way of effecting this is evident, for without some

eight grains; the same measure of pure water weighs one pound, avoirdupois*.

If the specific gravity of water be so much greater than that of atmospheric air, how is water retained in the atmosphere?

The water which is taken up by the atmosphere is not in an aqueous state, but is converted into vapour† by the matter of heat‡.

How is it that heat converts water into vapour?

A large portion of the matter of heat combin-

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such contrivance the purity of the atmosphere could not be preserved. Winds also may probably promote this union.

> "His wisdom guides the rushing wind,
> Or tips the bolt with flame:
> His goodness breathes in ev'ry breeze,
> And warms in ev'ry beam." DARWIN.

* The measure here alluded to is the common *wine* pint. From this one may deduce by calculation that a cubic foot of atmospheric air weighs nearly one ounce and a quarter, and a cubic foot of water 1000 ounces, avoirdupois.

† It is of importance to satisfy a young person of the truth of every thing we teach him, and whenever it can be done it ought not to be omitted. By inverting a glass goblet over a cup of hot water, the vapour will be seen to condense upon the cold glass and run down its inside; which will show that steam is *real* water, and can become water again.

‡ Here the pupil may be informed that water not only becomes converted into steam by heat, but that, when it is received into the atmosphere, if the air be warm it becomes so far changed by its union with the matter of heat as to be perfectly invisible. In this state it occupies a space 1400 times greater than in its ordinary liquid state.

ing chemically with water renders it specifically *lighter;* which is the cause of its rising, and mixing with the atmosphere*.

Is this effected in any of the great operations of nature?

Yes: a great part of the rain which falls upon the earth becomes changed at length into vapour†, and rises into the air in that state to form clouds.

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* An instrument has been invented for showing the relative moisture of the atmosphere, called an *hygrometer*. This instrument shows when aqueous vapour dissolves with difficulty in the atmosphere, or when vapours are about to precipitate upon the earth—but it will not indicate the real quantity of water in any given portion of atmospheric air. There is a great variety of these instruments, all made with porous substances, which contract and dilate according to the dryness or moisture of the air. Slips of whale-bone, strings of cat-gut, and the beard of the wild oat, are the substances most commonly employed in fabricating these instruments.

† Bp. Watson found that, even when there had been no rain for a considerable time, and the earth was dried by the parching heat of summer, it still gave out a considerable quantity of water. By inverting a large drinking-glass on a close-mown grass-plat, and collecting the vapour which attached itself to the inside of the glass, he found that an acre of ground dispersed into the air above 1600 gallons of water in the space of 12 hours of a summer's day.

The ocean loses many millions of gallons of water hourly by evaporation. The Mediterranean alone is said to lose more by evaporation than it receives from the Nile, the Tiber, the Rhone, the Po, and all the other rivers that fall into it. This water is conveyed by the winds to every part of the continents:

What is the cause of the waters of the earth being thus vaporized?

As the rays of the sun warm the ground*, a portion of the matter of heat combines with a portion of the water of the earth, and converts it into vapour†.

—these it fertilizes in the form of rain, and afterwards supplies the rivers, which flow again into the sea. This is one of those continual circulations whereby all matter is made to subserve various purposes, which have been devised by the Creator for the promotion of his beneficent designs.

"The bounteous sun
Lifts the light clouds sublime, and spreads them thin,
Fleecy and white o'er all-surrounding heaven."

In our climate evaporation is found to be about four times as much from the vernal to the autumnal equinox, as from the autumnal to the vernal. Heat facilitates all solutions; and the greater the difference between the temperature of the air and the evaporating surface, the greater will be the evaporation.

* In winter, the earth at eighteen inches depth is warmer than the air; in summer, the air is warmer than the earth at that depth: these effects are owing to the earth being a bad conductor of heat.

† The action of the sun upon the earth in producing vapours, &c., is easily explained on chemical principles. Nicholson, or any of the other modern writers on natural philosophy, may be consulted. The shelter which is afforded to the earth by clouds, mists, &c., is due to the operation of this cause.

To this all-pow'rful principle we owe
The copious mists which shield this world below;
Which give it how to bear the solar rays,
And roll unscorch'd beneath the torrid blaze.

But what causes the vapour to rise in the air?

If a cork be placed at the bottom of a bason of water, it rises immediately to the top, because it is specifically lighter than the water*: so vapour rises in the air, because it is specifically lighter than the air†.

What becomes of the water which thus evaporates from the earth?

It occupies the lower regions of the atmosphere‡, and is preserved there partly dis-

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[*] I have introduced this and other very familiar examples, because I think it of consequence that those who have the care of very young people should encourage them to inquire the *cause* of every thing which they see around them. A preceptor, who is well qualified for his employment, will not think any thing too trivial which can furnish him with an opportunity of imparting useful knowledge.

[†] It is evident that water exists in the atmosphere in abundance, even in the driest seasons and under the clearest sky. There are substances which have the power of absorbing water from the air at all times; such as the fixed alkalies, and sulphuric acid; the latter of which will soon absorb more than its own weight of water from the air when exposed to it.

[‡] There can be no doubt but that in general the vapours occupy the lower strata of the atmosphere: that they sometimes ascend very high, is also true; for it is well known that clouds are seen *forming* above the tops of the highest mountains. Indeed, the clouds *begin* to form always at some considerable height. Dr. Thomson, vol. iii. 373.

"At first a dusky wreath they seem to rise
Scarce staining ether; but by swift degrees,
In heaps on heaps, the doubling vapour sails
Along the clouded sky."

solved* in air†, and partly in the state of elastic vapour.

How is this vapour formed into clouds?

After it has remained some time in the atmosphere, it becomes in a measure condensed by causes unknown to us‡; and the particles of wa-

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* Persons who have been in the habit of making observations on the clouds may have sometimes noticed a cloud, which appeared to be just in the act of precipitating, suddenly arrested by a warm current of air, and entirely dissolved thereby, so as to become in a few seconds invisible. This is the same kind of solution as takes place whenever a warm breeze passes over a river, or the ocean. Whenever the air is ponderous, and susceptible of holding the aqueous vapour in solution, the mercury in the barometer rises up to 30 or upwards: when lighter, and liable to suffer the vapours to coalesce, its pressure is less on the base of the barometer, and the mercury falls. See a further account of the barometer in the next chapter.

† By the experiments of Saussure it appears that a cubic foot of atmospheric air will hold eleven grains of water in solution. From this property of the air we derive many advantages. It has a tendency to preserve every thing on the face of the earth in a proper degree of moisture. In one season of the year, in the interior parts of Africa, a wind prevails called the *Harmattan*, which is so extremely dry that household furniture is destroyed by it; the pannels of wainscots split; boarded floors are laid open; and the scarf skin of the body peels off, during its continuance. Were it not for the property which atmospheric air has of holding water in solution, this would be the case every where.

It appears from the experiments of some aëronauts, that the air is much drier in the higher regions than it is near the surface of the earth. Phil. Mag. vol. xix. 378.

‡ The formation of clouds was formerly attributed to the

ter of which it is composed unite, and form small hollow vesicles, which accumulate together* and produce clouds.

What further changes take place in this aqueous vapour?

By the operation of causes which are also in a great measure unknown, the clouds after a time become further condensed, and are converted into water†.

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solution of water in atmospheric air, and the production of rain to the mixture of airs of different temperatures; but there are so many difficulties attending every hypothesis, that I believe chemists in general now consider these operations of nature inexplicable. The subject is well investigated by Dr. Thomson, in vol. iii. of his System of Chemistry; and he concludes from all the facts, that "the formation of clouds and rain cannot be accounted for by a single principle with which we are acquainted." It is, however, probable that *electricity* alone is the primary cause, and that all the phænomena of nature may originate from this source.

* Saussure conjectures that it is the electrical fluid which surrounds these vesicles, and prevents them from dissolving in the air. These vesicles are said to be from 1.380 to 1-190th of a line in diameter.

An elaborate essay, by Luke Howard, esq. on the various forms which clouds assume, may be seen in the 16th and 17th volumes of the Philosophical Magazine.

See Dr. Darwin's theory of rain and dew, in Notes to the Botanic Garden, part i. pages 114 and 169.

† It has before been remarked, that a portion of the water which rises in vapour is held in *solution* by the atmospheric air. When two opposite currents of air meet, of different tempera-

What is the consequence of this change of vapour into water?

When the vapour is condensed, it becomes too heavy for the air to support, and falls down in rain*, hail, or snow.

What is the use of this constitution of nature?

This principle of evaporation is of very gene-

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tures, the vapours are sometimes condensed thereby, and rain follows. All the known gases have also the property of taking up water and holding it in solution.

It may be remarked, that if the temperature of our atmosphere had been 212°, or upwards, rain could never have fallen upon the earth; for the water taken up by evaporation would have been converted into a *permanently* elastic fluid. It is impossible ever to contemplate the various ways in which the different operations of nature are made to correct and balance each other, without being struck with the infinite comprehension of the Divine mind, which could thus foresee the tendency of every law which it was about to establish. How many cases are there in which the slightest oversight would have produced the destruction of a world!

* It may be observed that rain not only affords a proper degree of moisture to the vegetable creation, but is of service in bringing the soils into a proper state to perform their office. *Dry* earth of itself has little effect; but when *moistened* it has the property of decomposing atmospheric air, and of conveying its oxygen to the roots of those plants which vegetate within it. We are indebted to Humboldt for the knowledge of this fact.

> "The clouds consign their treasures to the fields,
> And, softly shaking on the dimpled pool
> Prelusive drops, let all the moisture flow
> In large effusion o'er the freshen'd world."

ral utility[*]: it is subservient to many natural processes, and is perpetually of use to man in every occupation of life[†].

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[*] This principle of evaporation not only is the primary cause of all rain, mist, dew, &c., but it moderates the effects of the sun's heat, by carrying off an immense quantity of caloric in combination with the aqueous vapours. Were it not for the cold produced by evaporation, we should faint under any great bodily exertion, or die by excessive heat. But Nature, always provident, has furnished man with a fluid, the product of an animal secretion, which, insensibly perspiring and becoming evaporated from the surface of the body, is the vehicle which carries off the superabundant heat as fast as it is generated. Cold-blooded animals, whose temperature is regulated by the medium in which they live, never perspire; but man, who was intended to live in a variety of climates, and designed for active exertion, is thus preserved from the effects of heat, which would otherwise be destructive. The blood of an inhabitant of the torrid zone is no warmer than that of an inhabitant of the mountains of Lapland; which may be proved by placing a thermometer upon the tongue or under the arm. How various are the means which have been adopted for the promotion of our convenience and comfort!

The operation of this principle may be made apparent by the following experiment: Take a small tube with a little water in it, fold a little lint close round it, and, having immersed it in ether till the lint is soaked through, hold it in the air for the ether to evaporate. The cold produced by this evaporation will cause the water in the tube to freeze. If the outside of the glass tube be scratched with a flint or a diamond previous to its being wet by the ether, the effect will more readily take place.

[†] A little reflection would convince any one of the importance of the principle of evaporation. Innumerable instances of its use might be adduced: suffice it to say, that without it

What is the ultimate use of this principle?

The Almighty has contrived that moisture should continually rise from the earth, and from the various bodies upon its surface, to shield this world of ours from the intense heat of the sun, and to return in rain to water the ground, causing grass to grow for the cattle, and corn and herbs for the service of man*.

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neither grass nor corn could be sufficiently dried to lay up for use. Our clothes when washed could not be dried; neither could a variety of the most common operations be carried on, which conduce much to our comfort and convenience.

* It is a characteristic of the works of creation that they will bear examination, and that the more they are examined the more pleasure they afford. The simplicity of the means which NATURE has chosen for performing the necessary operation of watering the earth, must strike every one who has any relish for what is grand and excellent. And surely the consideration of such subjects is not without its use; for, "who can meditate on the order observable in NATURE, and not endeavour to reduce his conduct to a similar standard of regularity?"

CHAP. II.

OF ATMOSPHERIC AIR.

What are the obvious properties[*] *of atmospheric air?*

Fluidity[†], elasticity[‡], expansibility, and gravity.

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[*] The habitable and cultivated parts of the earth are lavishly adorned with every thing to gratify the eye; the diversified appearance communicates pleasure, and prevents satiety; while the whole is surrounded by an atmosphere which preserves vegetable and animal life. It may be remarked, that to the *transparency* of this atmosphere we owe all the pleasure we receive from the variegated prospects which the earth affords.

[†] The fluidity of the air was considered in the last chapter. See pages 33, 39.

[‡] If a bladder be tied up with a very small quantity of air within it, and put under the receiver of an air pump, it will be seen to inflate gradually as the pump is exhausted, till it becomes of its full size; owing to the *elasticity* of the small quantity of air within the bladder, which dilates in this manner, as the atmospheric pressure is removed. A wrinkled apple placed under the receiver of an air pump becomes plump and smooth, from the same cause. The elasticity of the air is such, that Mr. Boyle caused it to dilate by means of an air pump till it occupied nearly fourteen thousand times the space that it usually does.

The elasticity of the air is proved by carrying a bladder half full of air to the top of a high mountain; for the air will be perceived to expand gradually as it approaches the summit.

What do you mean by the elasticity of the air?

If atmospheric air be compressed[*] into a small compass, it has the property of recovering its former state, as soon as the pressure is removed; which is called its elasticity[†].

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[*] Atmospheric air may be compressed into about the 128th of its usual volume; though, if an apparatus could be procured of sufficient strength, it might doubtless be compressed to a much greater degree: but owing to its elasticity it would regain its original bulk the instant the pressure was removed. Saussure made use of an instrument to show the elasticity of the air, which he called a *manometer*. It was a barometer enclosed in a well luted globe. Being thus enclosed, it was only sensible to the elasticity of the air within the globe. Berthollet's Chemical Statics.

[†] It is now generally supposed that the air owes its elasticity to the *caloric* which it contains; and that, if it could be deprived *entirely* of its caloric, it would lose its elastic form.

The rebounding of a common foot-ball would be a familiar instance to explain the elasticity of the air to a child.

Bubbles of air rising from the bottom of a glass of water will be seen to dilate as they rise to the surface; owing to the pressure of the liquor becoming less and less.

The air gun and the forcing pump are constructed on this principle. It is by this property of air that fishes are enabled to rise and sink in the water; nature having furnished them with an *air-bladder*, which they have the power of contracting or dilating at pleasure. When the animal compresses this bladder, its whole volume becomes less, and it sinks in the water: when the pressure is removed, the air within the bladder instantly expands, and the creature is enabled to rise.

Mr. Gregory has remarked that, if the air were not elastic, and so fluid as to be easily put in motion, there would be an end to all the melody and harmony which now so much delight us.

What is meant by the expansibility of the air?

The expansibility of the air is its property of being rarefied by heat, so as to occupy a larger space than it otherwise would*.

How far does the atmosphere extend?

The atmosphere is several miles high, but how far it extends is not exactly known†.

How admirably is every thing contrived, that it may not only administer to our wants, but be subservient to our pleasures also! That *music* was designed by the Deity to produce particular effects on man, might be shown very satisfactorily; but there is not room in this place for such a discussion;—though one may say with Mr. Hayley,

> "That Heaven is pleased, when this bright power
> Dispels the clouds of earth, too apt to lower
> On every human mind, in life's precarious hour."

* If the neck of a bladder, containing a small quantity of air, be closely tied up and held to the fire, the swelling of the bladder by the rarefaction of the air within it, will afford an idea of the *expansibility* of the air.

Mr. Robins has calculated, that the air which is disengaged in the firing of gunpowder is rarefied by the heat, so as to occupy a thousand times the space of the whole of the gunpowder employed.

The dilatation or expansion which bodies experience by a given elevation of temperature, is much more considerable in elastic fluids than in liquids. Atmospheric air is an instance of the truth of this chemical axiom. Whenever this expansion takes place, caloric is absorbed.

† If the atmosphere were of the same density throughout, its height might be known by its effect in raising a column of water or mercury; but as it increases in rarity the higher it

What is the use of the atmosphere?

The atmosphere, which is the air we breathe, is necessary for the support both of animal and vegetable life*.

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ascends, and is probably extremely rare in the higher regions, we cannot possibly tell how far it may extend. It was attempted to calculate the extension of the atmosphere by ascertaining its comparative rarity at different heights; but this also was found to be impracticable. Since then, it has been estimated by the length of our twilight, and supposed to be about forty-five miles high. If we had no atmosphere, we should be in total darkness at the *instant* the sun sinks below the horizon; but as the sun illuminates the atmosphere for some time before it rises, and after it has set, the light is reflected by the atmosphere to the earth. We cannot but admire the *simplicity* of this contrivance, to prevent the sudden transition from light to extreme darkness.

"From night to day, from day to night,
The *dawning* and the *dying* light
Lectures of heavenly wisdom read;
With silent eloquence they raise
Our thoughts to the Creator's praise,
And neither sound nor language need."

* It has been ascertained by experiment, that no other gaseous body with which we are acquainted can be substituted for atmospheric air. All the known gases have been tried; but they all prove fatal to the animal which is made to breathe them. (Dr. Thomson, vol. iv. 709.) Water absorbs air when exposed to the action of the atmosphere, and thence becomes a fit element for the various tribes of creatures which inhabit it: and when covered with a crust of ice, cavities are formed in the ice as it freezes, by which means a communication between the external air and the subjacent water is preserved; in order to support the life of those beings which reside there.

Is the atmosphere of use in any other respect?

The atmospheric air is necessary in every instance of combustion*: it ministers to several of the pleasures which we derive from our senses†;

> " The vital air
> Pervades the swarming *sea*, and heaving earths,
> Where teeming Nature broods her myriad births;
> Fills the fine lungs of all that breathe or bud,
> Warms the new heart, and dyes the gushing blood;
> With life's first spark inspires the organic frame,
> And, as it wastes, *renews* the subtil flame."
>
> DARWIN.

It is to the presence of air that water is indebted for its agreeable taste. Boiling deprives it of the greater part of it; hence the insipidity of boiled water.

[*] There is one exception to this axiom. If a combustible substance be mixed with one fourth or one half its weight of nitre, or with oxygenized muriate of potass, it will burn if atmospheric air be excluded. But this is owing to oxygen, one of the principles of the atmosphere, being afforded by these salts. See chap. xii. on Combustion.

[†] Were it not for atmospheric air, we should be unable to converse with each other; we should know nothing of sound, or of smell, or of the pleasures which arise from the variegated prospects which now surround us. It has been well remarked, that, if the Deity had intended only to give us existence, and had been indifferent about our happiness or misery, all the necessary purposes of hearing might have been answered without harmony; of smell, without fragrance; of vision, without beauty.

Perhaps nothing tends to give so satisfactory an assurance of the goodness of the ALMIGHTY, as the consideration of the various *uses* to which the different substances in Nature may be applied. With this view I copy what an elegant French it gives buoyancy to the clouds, and enables the feathered creation to transport themselves with ease from one part of the earth to another *.

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writer has said on this necessary fluid. "In the use of atmospheric air, *man* is the only being who gives to it all the modulations of which it is susceptible. With his voice alone, he imitates the hissing, the cries, and the melody of all animals; while he enjoys the gift of speech denied to every other. To the air, he also sometimes communicates sensibility; he makes it sigh in the pipe, lament in the flute, threaten in the trumpet, and animate to the tone of his passions even the solid brass, the box tree, and the reed. Sometimes he makes it his slave: he forces it to grind, to bruise, and to move for his advantage an endless variety of machines. In a word, he harnesses it to his car, and obliges it to waft him over the stormy billows of the ocean."

* Messrs. Robertson and Saccharoff, who ascended with an air balloon from Petersburgh, in June 1804, took some live pigeons with them. At different heights they gave liberty to their birds, who seemed not very willing to accept it. The poor animals were so terrified with their situation, that they clung to the boat till forced from it; when it appears their fears were not groundless; for, on account of the rarity of the air, their wings were nearly useless, and they fell towards the earth with great rapidity: the second struggled with eagerness to regain the balloon in vain; and the third, thrown out at the greatest elevation, fell towards the earth like a stone, so that they supposed he did not reach the earth alive. Retrospect, vol. i. 94. This relation affords a fresh instance of the harmonies of Nature, and of the suitableness of every creature to the medium in which it was designed to live. The density of the air, near the surface of the earth, we see is exactly what was requisite for the residence of the feathered race; and the specific gravity of every individual, of every species, is just suf-

But what is the use of the atmosphere being extended so far above the surface of the earth?

It is this extension of the atmosphere which occasions its *weight;* and this great weight produces many important effects in the œconomy of nature*.

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ficient to enable it to occupy that element, and to move within it at all times with ease and safety. The most acute fatalist would surely be puzzled to account for these congruities. Let us attribute them to the contrivance of that Being, who never bestows existence but for the sake of conferring felicity, and we are at once in possession of the most satisfactory solution.

* The pressure of the atmosphere may be shown by a simple experiment. Place a card on a wine-glass *filled* with water; then invert the glass, and the water will not escape; the pressure of the atmosphere on the outside of the card being sufficient to support the water.

The same thing may be shown by a different experiment. Invert a tall glass jar in a dish of water, and place a lighted taper under it. As the taper consumes the air in the jar, its pressure becomes less on the water immediately under the jar; while, the pressure of the atmosphere on the water *without* the circle of the jar remaining the same, part of the water in the dish will be forced up into the jar, to supply the place of the air which the taper has consumed. Nothing but the pressure we are speaking of, could thus cause a part of the water to rise within the jar, above its own level.

Again, the reality of atmospheric pressure may be explained and demonstrated by a common barometer, merely by showing how it acts upon that instrument.

> " In tubes of glass mercurial columns rise,
> Or sink, obedient to the incumbent skies."

It is this action of the atmosphere which enables the limpet

What are the effects of the weight of the atmosphere?

It is owing to the weight of the atmosphere that we are enabled to raise water by the common pump*, and to perform many other useful operations.

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to attach itself to the rocks. It forms a vacuum in its pyramidal shell, and the pressure of the atmosphere supports it where it wishes to remain, without any further exertion of its own.

* It is impossible for a youth to understand this, unless it be particularly explained to him; which may be done by telling him, that the atmosphere presses equally upon the whole surface of the water in the well, until the rod of the pump is moved; but that, by forcing the rod down, the bucket compresses the air in the lower part of the pump tree, which being elastic, forces its way out of the tree through the valve; so that when the bucket is again raised, that part of the pump tree under the bucket is void of air; and the *weight of the atmosphere* pressing upon the body of water in the well, forces up a column of water to supply its place; that the next stroke of the pump rod causes another column of water to rise, and that, as long as the bucket fits the pump tree close enough to produce a vacuum, a constant stream of water may be drawn from below. By cutting a piece of pasteboard in the form of a valve, and fixing it in a glass tube of a large bore, it will be no difficult thing to explain how the successive columns of water force up the valve in the pump tree, and how that valve supports the water when raised, and prevents its return. See Additional Notes, No. 12.

" Press'd by the incumbent air, the floods below,
Through opening valves, in foaming torrents flow,
Foot after foot in lessen'd impulse move,
And rising seek the vacancy above." DARWIN.

What other advantages do we derive from this extension of the atmosphere?

If we had little or no atmosphere, we should have no cold water; for the waters on the face of the earth would all evaporate at a very inferior temperature*: besides, the arterial vessels of all

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A common syringe (which may be bought for a few pence) will show the action of atmospheric air in pumping.

When a child sucks at the breast, it forms a vacuum with its mouth, and the milk flows on the same principle.

In like manner the boy forms a vacuum between a piece of wet leather, tied to a string, and a pebble stone; and, by means of the pressure of the atmosphere, is enabled to lift the pebble from the earth and carry it about, suspended by the leather. The common syphon is indebted to this pressure also for its action.

* On the tops of very high mountains, water will boil much sooner than on the plains, where the atmosphere is heavier; and it is known that many spirituous liquors, such as ether and spirits of wine, lose a great part of their qualities when exposed at such heights. See some interesting experiments in the first chapter of Lavoisier's Elements, also Additional Notes (at the end of this volume), No. 3.

The quick evaporation which would take place if we had no atmosphere, may be shown by a common instrument, invented by Dr. Franklin, called a pulse-glass. It is a small tube with a bulb at each end, exhausted of its air, and containing a small quantity of spirits of wine. If this instrument be held sloping, with one end in the palm of the hand, the heat of the hand will quickly cause the spirit to boil; but the vapour rising to the other end, becomes condensed as soon as it comes in contact with the cold glass. This is a very cheap and simple experiment, and shows that a very small degree of heat would be organized beings would be so constantly distended, that animal and vegetable life would be endangered.

How are waters and other fluids preserved to us by the weight of the atmosphere?

The weight of the atmosphere, pressing on the water, binds it down as it were, and prevents the usual heat of the sun from converting this and all other fluids on the face of the earth into vapour*.

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sufficient to evaporate most of our fluids if we had no atmosphere. This instrument is also calculated to show that evaporation produces cold; for the instant that the spirit begins to boil, a sensation of sudden cold is felt on that part of the hand where the bulb rests.

It is the principle of *evaporation producing cold* that occasions the injury which persons sustain by sitting in wet clothes. In these circumstances, it is not the water that hangs *upon* them, which produces the mischief, but the sudden loss of a large portion of caloric, which is carried off from the body by the evaporation of this water. If a healthy person were closely covered up with his wet clothes, so that no evaporation could take place, he would probably sustain no injury.

* That the waters on the face of the earth would be dissipated in vapour by a small degree of heat, if we had no atmosphere, may be shown by the following simple experiment:—Procure a bottle with a very long neck, *fill* it with boiling water, and cork it close so as to exclude the air. Then if it be put to stand in a bason of cold water, the water will sink in the neck of the bottle as it cools. This shrinking of the hot water will produce a vacuum in the upper part of the bottle, and the water within it will be seen to recommence its boiling with great violence. This can be owing to nothing but the cork taking off the pressure of the atmosphere from the water. In

How does the weight of the atmosphere operate, so as to be beneficial to the animal and vegetable creation?

The uniform pressure of the atmosphere on the *exterior* of all organized beings counterpoises the

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like manner, water which has been cooled many degrees below boiling will begin to boil again if placed under the receiver of an air pump, as soon as we begin to exhaust the receiver of its air. Under the pressure of the atmosphere water boils at 212°, but in vacuo it boils when heated only to 67°. On the contrary, if additional pressure be given to water by a Papin's digester, it may be heated to 400°, without ebullition. Lead has often been melted by the water heated in these digesters.

At the boiling fountain in Iceland the water is thrown to the height of 90 feet, and is still boiling-hot when it falls to the ground. This water, therefore, must have been much hotter, in its reservoir, than the boiling point of water. See Troil's Account of Iceland.

Some philosophers have asserted that, if atmospheric pressure were entirely removed, all substances on the face of the earth, solid as well as fluid, would be dissipated in vapour.

If a small thin glass jar be half filled with good ether, and placed within another jar half filled with water, and both be put under the receiver of an air pump, when the air is exhausted the ether will boil, and the water will be frozen. The cause of these effects may be thus explained:—When the pressure of the atmosphere is removed by the air pump from the surface of the ether, its own latent caloric occasions its expansion, and, absorbing caloric from the water, it becomes converted into gas; and the water, having lost its caloric of fluidity, becomes ice.

The

internal pressure of the circulating fluids, and preserves the vessels in due tone and vigour*.

The best elucidation of the nature of the pressure of the atmosphere, which I have seen, is in "Brisson's Physical Principles of Chemistry," section 31, and the following.

* Were it not for the pressure of the atmosphere constringing the vessels in men and vegetables, the elastic fluids contained in the finer vessels would inevitably burst them, and life become extinct. Count Zambeccari and his companions, who ascended with a balloon to a great height on the 7th of November 1783, found their hands and feet so swelled, that it was necessary for surgeons to make incisions in the skin. They ascended to so great a height, that the pressure of the atmosphere was not sufficient to counterbalance the pressure of the fluids of the body.

Persons who have delicate constitutions need not wonder that they are generally much affected by a change in the atmosphere, when they learn that often in the course of a few hours the atmospheric pressure, on each individual, is increased or diminished from one hundred weight to half a ton weight; while the *internal* pressure of the circulating fluids remains the same. Supposing a man's body to contain 15 square feet of surface, (which is near the truth,) he will sustain a body of air upwards of fourteen tons weight. But it is necessary to remark that the air presses upwards, downwards, and sideways, in every direction; and that it is owing to this equal pressure that we are not injured by the vast weight of the atmosphere; for the equal pressure, on all sides, resists as much as it is resisted.

Whenever I hold my hand out in this fluid, I feel no weight upon it, because the pressure under and above my hand is equal: but if I lay my hand on a hollow cylinder of glass, placed on the plate of an air pump, and exhaust the air out of

What is the weight of the atmosphere?

It is about 2160 pounds upon every square foot. A column of air an inch square weighs about 15 pounds*.

What other advantages do we derive from this immense atmosphere?

The great thickness of the atmosphere gives a proper temperature to the rays of the sun: it also reflects those rays so as to give a lucid brightness to every part of the heavens†; and is the cause

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the cylinder, I become immediately conscious of something that presses it so forcibly to the glass, that I cannot release it. The prop is now gone; I have no pressure under my hand; a column of air, 45 miles high, forces it down by its weight, and I must let in the air under it, before the hand can be withdrawn.

Mr. Coates computed the weight of the air which presses upon the whole surface of the earth, and found it to be equal to that of a globe of lead sixty miles in diameter.

[*] A column of air of the height of the atmosphere, when greatest, is equal to a column of water 35 feet high, or a column of mercury of the same size 30½ inches high. Hence water will not rise in a pump more than 35 feet, nor mercury in a barometer stand higher than 30½ inches. See Additional Notes, No. 12.

A quart measure of atmospheric air weighs about 17 grains.

[†] If there were no atmosphere surrounding the earth, only that part of the sky would appear light in which the sun was placed; and if a person should turn his back to the sun, he would directly perceive it as dark as night; for in that case

of those dews and rains which make the earth fruitful*.

Have you learnt any thing of the nature† of the air which forms the atmosphere of this earth?

Yes: it is a mixture chiefly of two different airs‡,

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there would be no substance to reflect the rays of the sun to his eyes. It is owing to this reflection that the sun enlightens the earth some time before it rises, and some time after it sets. See this explained with perspicuity by Gregory, in his Astronomical Lessons, page 78—82.

* The atmosphere is the cause of evaporation: it is the atmospheric air which holds the aqueous vapours in solution, and preserves them in a gaseous state till they are condensed again into rain.

† For the discovery of the composition of atmospheric air we are indebted to Scheele, whose genius when very young enabled him to break the trammels of a dependent situation, and whose subsequent investigations of Nature have immortalized his memory.

‡ Pure atmospheric air is composed of three gaseous substances only, but it is perpetually contaminated by a variety of exhalations from the earth. "The atmosphere is a vast laboratory, in which Nature operates immense analyses, solutions, precipitations, and combinations: it is a grand receiver, in which all the attenuated and volatilized productions of terrestrial bodies are received, mingled, agitated, combined, and separated. Notwithstanding this mixture, of which it seems impossible for us to ascertain the nature; the atmospheric air is sensibly the same, with regard to its intimate qualities, wherever we examine it." FOURCROY.

which are chemically combined[*] in certain proportions[†].

What do you call these airs which compose our atmosphere[‡] *?*

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[*] When the nature of atmospheric air began to be understood, it was imagined that it was a mere *mixture* of oxygen gas and nitrogen gas: but we have now abundant reason to believe that it is a real chemical compound; that is, that the oxygen and nitrogen form atmospheric air by a chemical union. Mr. Dalton, an ingenious modern chemist, is still of the first opinion; but an experiment made by some friends of mine on a large scale, proves, I think, the fallacy of his theory. In order to produce sulphuric acid, without the intervention of nitre, they caused a stream of atmospheric air to be thrown upon burning sulphur, from a very powerful bellows constructed for the purpose; and though the experiment was made under the most favourable circumstances, and the blast kept up for three days, no portion of sulphuric acid was formed. Does not this prove that oxygen has a greater affinity for nitrogen than for sulphur, and that atmospheric air is not a mixture, but a chemical compound?

[†] According to Mr. Davy, the air of Europe, Asia, Africa, and America, differs very little in the proportion of its ingredients. Journal Royal Instit.

[‡] Atmospheric air is a chemical mixture of two distinct and *solid* substances, viz. oxygen and nitrogen, rendered aërial by the expansive power of caloric: it likewise contains a portion of carbonic acid gas.

Oxygen and nitrogen, combined in various proportions, form also no less than four other compounds, viz.

Nitric acid consisting of about	4 parts oxygen	to 1 of nitrogen.
Nitrous acid of,	3 do.	to 1 do.
Nitrous gas of,	2 do.	to 1 do.
Nitrous oxide of,	1 do.	to 2 do.

They are called oxygen air* and nitrogen air.

Are oxygen and nitrogen the only substances which enter into the composition of the atmosphere?

No: atmospheric air contains also one part in every hundred of carbonic acid gas†, and several adventitious substances.

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[*] The respirable part of atmospheric air has been called oxygen, on account of its acidifying principle; the other part has been termed azote, from its known quality of killing all animals that are obliged to breathe it, when separated from oxygen. The terms are taken from the Greek language. I have in this work adopted *nitrogen* in preference to azote, because it is the base of nitric acid, and it agrees in termination with oxygen and hydrogen. Carbonic acid gas and hydrogen gas are as incapable of supporting life as nitrogen; therefore there is no reason why one should be called azote more than the other.

It should be remarked, that oxygen requires *light* as well as caloric in order to convert it into vital air. During combustion, the vital air gives out this light in every direction.

[†] If a pure alkali or an alkaline earth be exposed to the atmosphere, it will gradually absorb carbonic acid. This is also the case with several of the metallic oxides. As atmospheric air is always furnished with carbonic acid, no wonder that so large a number of the salts are found in the state of carbonates.

Carbonic acid gas is found to exist in the atmosphere not only near the surface of the earth, but at the greatest heights; which is a proof that it is not a mere mixture, but that it is chemically combined with the air. Saussure found it at the top of Mont Blanc, which is esteemed the highest point of the old continent. However, it is probable that the proportion of carbonic acid is not so large at great heights as it is near the earth; for the unfortunate philosophers who attended La Pe-

What other substances are found in atmospheric air?

Besides carbonic acid gas, which is chemically combined with the air*, it holds a portion of water in solution†; and sometimes

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rouse in his last voyage could not detect it in the atmosphere at the summit of the peak of Teneriffe. See La Perouse's Voyage.

Dr. Thomson has calculated, that on the supposition of there being 1 per cent. of carbonic acid dispersed throughout the atmosphere, its absolute quantity would amount to more than one hundred millions of hundred millions of pounds avoirdupois; and remarks "that this enormous quantity undoubtedly serves some valuable purpose in the atmosphere, though our knowledge of the changes which go on in that great laboratory is at present too imperfect to enable us even to conjecture the uses to which it may be applied." *Some* of the uses of carbonic acid gas in atmospheric air, I think, are very apparent. Without it none of our buildings would acquire the necessary degree of firmness, as it is well known that mortar hardens in consequence of the absorption of this gas; and if the atmosphere was entirely divested of it, it is doubtful whether plants of all kinds would vegetate as they now do; for its base is the proper food of vegetables.

"Unlavished Wisdom never works in vain."

* Carbonic acid gas is nearly twice as heavy as common air: hence it is evident that it must combine *chemically* with the atmosphere, or it would be found only near the surface of the earth. If it was merely *mixed* with atmospheric air, its gravity would prevent it from ascending to any great height.

† Upon an average, atmospheric air contains about 1 per cent. of water in the state of elastic vapour.

contains hydrogen and carburetted hydrogen gases*.

What are the sources of these other gases?

Carbonic acid gas is constantly formed by the respiration of animals and by combustion†; and hydrogen and carburetted hydrogen gases arise from various sources, particularly from marshes, stagnant pools, &c., all which are prejudicial to the animal creation.

If carbonic acid air and carburetted hydrogen air are prejudicial to animal life, how are they corrected in the atmosphere?

These airs, which would cause the death of

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[*] It is remarkable, that whenever aqueous vapour is added to atmospheric air an augmentation of volume is the consequence, and damp air is always specifically lighter than dry air. This shows that it is not a mere mixture, but a chemical combination.

From the frequent decompositions which are taking place upon the surface of the earth, the atmosphere must always contain a portion of hydrogen gas; but we have no ready means of detecting it.

[†] The quantity which is daily formed by these processes is so great, that it must have increased rapidly, had not the Almighty provided means for its being as rapidly decomposed. The wisdom and goodness of this appointment must be apparent to those who know that whenever atmospheric air becomes charged with one tenth of this gas, it is unfit for promoting combustion, and is fatal to most animals that are obliged to breathe it.

any animal obliged to breathe them*, are the proper nutriment of vegetables, and nature has endowed them with organs for their decomposition.

You have spoken of different gases; what do you mean by gas?

When solid substances are rendered perma-

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* Every chemist must be aware that a large quantity of *carburetted hydrogen gas* is perpetually evolved at the surface of the earth; he must also know that this gas is fatal to animal life. I could adduce a melancholy instance of a gentleman who inhaled it by mistake, and died almost immediately in consequence of it. How then has the all-wise Artificer of the world contrived to protect its inhabitants from the baneful influence of that immense quantity with which the atmosphere is perpetually contaminated? The means are as simple as they are important.—Vegetables are so constituted that carbon and hydrogen are the necessary food of plants, and conduce to the support of vegetable life: their vegetating organs seize the carbonic acid gas which comes within their reach, and while they appropriate the *carbon* to themselves, the *oxygen* is thrown off to renovate the atmosphere by its union with the nitrogen rejected by animal respiration. As all vegetables are in want both of carbon and hydrogen, there can be little doubt but that by their means the atmosphere is divested of carburetted hydrogen gas also. Thus, what is noxious to man is rendered beneficial to vegetables; and the oxygen which vegetables are not in want of, is separated by them in its utmost purity for the use of man. The wisdom, the simplicity, and the beneficence of this arrangement are so striking, and address us with so much effect, that the mind of the reader may be left to make its own reflections on the goodness of the Deity. See Additional Notes, No. 10 and 37.

nently aëriform by heat, the air thus produced is called a *gas**.

Is there any chemical means of analysing atmospheric air?

By the operation of different agents, the seve-

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* Van Helmont was the first chemist who made use of this term to denote an elastic fluid. He gave fixed air the name of *gas*.

All the simple gases are formed with a substance more or less *solid*, and caloric. It is caloric which separates the particles, and gives to the whole a gaseous form. In order to produce any of the gases, heat is generally made use of, though sometimes we have recourse to the acids for this purpose.

The gases are elastic, invisible, and permanently aëriform, unless condensed by chemical combinations.

The permanency of the gases appears to be owing to the strength of the affinity existing between caloric and their bases, which affinity resists every reduction of temperature.

When gases are produced by distillations, or by chemical mixtures, the radical of the gas is not merely heated by caloric, but caloric is chemically *combined* with it, and forms one of its necessary component parts. Some of the gases, such as muriatic acid gas, nitrous gas, &c., may be condensed by water; but in this case a new combination is formed by the acid and the water, and the caloric is disengaged in the form of sensible heat.

For an account of the method of collecting gases, and of transferring them from one vessel to another, consult Berkenhout's First Lines of Philosophical Chemistry, page 204, where the necessary apparatus is minutely described, and appropriate drawings are annexed.

The pneumatic trough which is used for these purposes was invented by Dr. Priestley. A common tub with a shelf fixed in it was what he first used; afterwards he was furnished with ral gases may be separated from each other, and the quantity of each ascertained[*].

Do you know the proportions of the different gases in atmospheric air?

There are about 22 parts of oxygen, 77 of nitrogen, and one of carbonic acid gas, in every 100 measures of atmospheric air[†].

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a very elegant apparatus which the amiable Duke of Rochefoucault sent him from Paris.

[*] The method of doing this may be seen in Priestley, or in Black's Lectures, to which I refer the reader.

The gases have been divided by some writers into two classes, viz. those that are *respirable,* and capable of maintaining combustion, and those that are *not respirable,* and incapable of maintaining combustion. It is remarkable that if we attempt to breathe any of the non-respirable gases, they stimulate the muscles of the epiglottis in such a manner, as to keep it perfectly close, and prevent, in opposition to our exertions, the smallest particle of gas from entering into the bronchia. Some modern atheists have asserted that the members of the animal body have acquired their adaptation to the wants of the individual by habit; and that they have been gradually formed to what we see them by repeated use from generation to generation; but here is an instance of the parts *refusing action,* for the preservation of the animal. This peculiar faculty therefore, as a celebrated writer has remarked in another instance, could not have grown out of the use of the parts though it had had an eternity to grow in. It can only be attributed to that beneficence of contrivance, which in so many instances excites our gratitude and admiration.

[†] The proportions, according to Lavoisier and other writers, are 27 of oxygen and 73 of nitrogen: and if they calculated by *weight,* these proportions will be near the truth, as the specific gravity of oxygen gas is greater than that of nitrogen gas.

Is there much difference in the nature of these gases?

Yes: they are of different and opposite qualities*.

The pupil may be satisfied with the truth of these proportions in various ways;—the following is the easiest:

A lighted taper will not burn in nitrogen gas a moment; if immersed in oxygen gas, it burns with a splendour too great for the eye to endure: but if three measures of nitrogen gas and one of oxygen gas are put into a jar inverted over water, and a lighted taper put into such mixture, it will burn exactly the same as it does in atmospheric air.

" If a few hundredth parts of oxygen only were wanting in atmospheric air, fire would lose its strength, candles would not diffuse such complete light, and animals would with difficulty separate the necessary quantity of the vivifying oxygen. On the other hand, if the atmosphere were more charged with oxygen than nitrogen, animals indeed would acquire a freer respiration; but let us consider the activity which fire would acquire by air of superior purity. We know that, on some occasions, the least spark excites the strongest flame in a combustible body, and which increases so much as to consume it in a few moments: candles *then* would be no sooner lighted than they would be destroyed, without answering any other purpose than that of dazzling us for a few moments: iron would be calcined, instead of acquiring from the fire that softness necessary for transforming it into various instruments, and which it cannot receive in a more moderate heat. Nothing would be capable of checking the progress of this destructive element, which is nourished by vital air, if this aëriform substance were not abundantly mixed with mephitic air, which serves to restrain it." Anthony de Marti on the Constitution of the Atmosphere.

* These gases are of such opposite qualities, that the one is sometimes called *vital* air; while the other, from its causing the

What are the properties of oxygen gas?

The oxygen gas in atmospheric air is the principle of combustion*, and the vehicle of heat†; and is absolutely necessary for the support of animal life‡.

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death of those who breathe it, is by the French chemists (as has before been remarked) called azotic gas.

* The necessity of oxygen for supporting combustion may be shown by the following simple experiment. Pour a little water on a flat dish, place two or three lighted wax tapers of different lengths in the water, and invert a tall glass jar over them. The flame of the different tapers will soon be seen to grow smaller, and at length will be extinguished in succession. That which is highest will be extinguished first, and the shortest taper the last, owing to the purer air occupying the lower part of the jar.

† "Dr. Higgins having caused a young man to breathe pure oxygen gas for several minutes, his pulse, which was at 64, soon rose to 120 beats in a minute. The advantage which may be derived to the sick, by increasing or diminishing at pleasure this natural stimulus in the blood, may be easily conceived; for, by abstracting a part of the oxygen from atmospheric air, the pulse may likewise be lowered at pleasure." (Thornton's Philosophy of Medicine.) See Additional Notes, No. 6 and 8.

Pure oxygen gas has been used also with success in cases of suspended animation.

Water impregnated with oxygen gas has been found a valuable remedy in several diseases. By depriving common water of atmospheric air by boiling, and then forcing oxygen gas into it, I have occasioned a large absorption of it, and have found that it retained it better than carbonic acid gas is retained by water.

‡ It has been proved by Mr. Hassenfratz, that oxygen is necessary to promote the vigour of plants as well as that of animals; and that to this end, a much larger quantity of oxygen

What is the nature of oxygen gas, when in a separate state?

Pure oxygen gas has the property of accelerating the circulation of all the animal fluids, and occasions the most rapid combustion of all combustible substances; so that it is the most energetic and powerful agent that we are acquainted with.

What is the specific gravity of oxygen gas?

Oxygen gas is a little heavier than atmospheric air*, and 740 times lighter than water.

What are the principal properties of nitrogen gas?

Nitrogen gas is chiefly distinguished by certain *negative* qualities, such as its being incapable of supporting combustion and animal life. It is

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is combined with snow, and in rain water, than in river or spring water.

"LEAVES, LUNGS, and GILLS, the vital ether breathe
On earth's green surface, or the waves beneath."

A collection of experiments on the effects of oxygen on animal and vegetable life may be seen in "Archer's Observations on Oxygen," 8vo. Dilly, 1798. See Additional Notes, No. 6.

* At the temperature of 54.50, when the barometer stands at 28 inches, oxygen gas is 12 drachms (or 1½ ounce) to each cubical foot; whereas nitrogen gas is only 10 drachms 48 grains to the cubical foot.

Oxygen gas is plentifully procured from nitre, or from the black oxide of manganese. Four ounces of nitre melted with a little slacked lime produced Mr. Ingenhouz 3000 cubic inches of vital air. See Additional Notes, No. 7.

uninflammable, and somewhat lighter than atmospheric air[*].

Seeing that nitrogen gas is injurious to animal life, what is the use of so large a quantity of it in atmospheric air?

Nitrogen gas has the effect of neutralizing, in some measure, the properties of oxygen gas, and rendering it fit for respiration and combustion[†].

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[*] Nitrogen enters into all animal substances, and generally in combination with carbon and hydrogen. It is also the base of ammonia, and of the nitric acid. It appears to be favourable to plants, as they grow and vegetate freely in this gas. It seems to be the substance which nature employs in converting vegetables to animal substances; and to be the grand agent in animalization. See Fourcroy's Philosophy of Chemistry chap. xi.

When nitrogen gas is required for experiments, it may be thus procured:—Take a few iron filings, mix them with a little sulphur, and moisten the mass with water. Put this mixture into a large glass jar, and cork it close. In a few days the oxygen will be absorbed by the mixture from the air which was previously in the glass, and the residuum will be found to be nitrogen gas. It may be procured also by digesting very dilute nitric acid with pieces of flesh, or on the muscular fibre.

[†] According to Trousset, the gas emitted by the skin is pure nitrogen. Annales de Chimie, tom. 45. 73.

"If the proportions of oxygen and nitrogen were reversed in atmospheric air, the air taken in by respiration would be more stimulant, the circulation would become accelerated, all the secretions would be increased, the tone of the vessels, thus stimulated to increased action, would be destroyed by over excitement; and, if the supply from the stomach were not equal to the consumption, the body must inevitably waste and decay."—(Dr. Lambe.) Hence the wisdom of the Deity, in the consti-

How is this change effected by nitrogen gas?

By the union of nitrogen gas with oxygen gas: the latter, which would burn every thing within its reach with an unparalleled activity, is, as it were, dissolved and diluted; and the nature of the former is so much enveloped by the latter, that the compound possesses properties different to either of these gases, so as to be fitted for every purpose for which it was designed*.

How does atmospheric air support life†?

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tution of atmospheric air, is as evident as in the nutritious quality of the food which he has provided for the support of the creatures of his formation.

* Though nitrogen gas is, by itself, so noxious to animals, it answers an important end when mixed with oxygen gas in atmospheric air. Were it not for this large quantity of nitrogen in the atmosphere, the blood would flow with too great rapidity through the vessels, and all animals would have too great spirits; the consequence of which would be, that the life of man would not be protracted to the length that it now is.

> "From Nature's chain, whatever link you strike,
> Tenth, or tenthousandth, breaks the chain alike."

Nitrogen gas has been medicinally administered with success in cases of increased irritability, such as inflammation, &c. Fourcroy.

† The necessity of atmospheric air, for the support of life, was exemplified by a melancholy accident which happened to two men in the bay of Dublin, who went to visit a wreck in a diving bell. Two barrels of fresh air were to be alternately sent down to them, and the contaminated air was to be let out by a stop cock at the top of the bell. But, by the contraction which ropes suffer in being wet, the bell turned round in its descent,

By giving out its oxygen and caloric to the blood*.

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and entangled the strings by which the divers meant to ring bells, and indicate their wants to the people on board the ship from whence they were lowered. Waiting too long for these signals, the bell was raised, and the divers were both found dead. They were not drowned, but died, like the unhappy people in the hole at Calcutta, for want of a supply of pure air.

* Dr. Priestley has shown, by a variety of experiments, that the blood perpetually receives oxygen gas (or what he calls dephlogisticated air) from the atmosphere, by the agency of the lungs. See his Experiments on Air.

" The blood is *purple* when it arrives at the lungs; but having there thrown off hydrogen and charcoal, it imbibes the vital air of the atmosphere, which changes its dark colour to a brilliant red, rendering it the spur to the action of the heart and arteries; the source of animal heat; and the cause of sensibility, irritability, and motion." Thornton's Philosophy of Medicine.

Black venous blood, exposed to the air, becomes red on its surface; and air, remaining confined over venous blood, loses its oxygen, so that what remains is found to be unfit for combustion. These facts prove that the vermilion colour of the blood is owing to the inhalation of oxygen gas.

" The internal surface of the lungs, or air vessels, in man, is said to be equal to the external surface of the whole body: it is on this *extended* surface that the blood is exposed, through the medium of a thin pellicle, to the influence of the respired air." Dr. Darwin. See Additional Notes, No. 8.

" 'Tis surely God
Whose unremitting energy pervades,
Adjusts, sustains, and *agitates* the whole.
He ceaseless works alone; and yet alone
Seems not to work: with such perfection framed
Is this complex stupendous scheme of things." Thomson.

What do you mean by caloric?

Caloric is the name which modern chemists have given to fire, or the matter of heat; a large portion of which is intimately combined with atmospheric air*.

Is the caloric, which is combined with the air we breathe, sufficient of itself to keep up the necessary heat of the body?

Animal heat is preserved *entirely* by the inspiration of atmospheric air. The lungs, which imbibe the oxygen gas from the air, impart it to the blood; and the blood, in its circulation, gives out the caloric to every part of the body†.

By the rise of the breast-bone in man, and the descent of the diaphragm, room is afforded for 42 cubic inches of atmospheric air at every drawing in of the breath. A deeper inspiration will give room for more than twice this quantity. Keill's Anatomy.

* This name was given by the framers of the new nomenclature to the matter of heat, which they always distinguish from the effect. Caloric is applied to fire, or the substance which produces the sensation we call heat, but never to the sensation itself, or the effect produced by fire. In this case, it is said that caloric raises the temperature of bodies, or, on the contrary, that the temperature is lowered by the loss of caloric.

† Dr. Menzies ascertained, that the blood in its passage through the lungs gains more than one degree of Fahrenheit's thermometer. Dr. Menzies on Respiration.

Dr. Crawford instituted a series of experiments, with a view to discover the cause of animal heat. In the course of his inquiry, he found that blood contains a much greater quantity of *absolute* heat than the elementary substances of which it is composed, and that in its change from venous to arterial blood, *How do clothes conduce to preserve the heat of the body?*

As the temperature of the atmosphere in this cli-

it acquires a greater *capacity* for caloric; by which admirable contrivance, any rise of temperature in the lungs which would be incompatible with life, is prevented.

Nothing can afford a more striking proof of creative wisdom, than this provision for the preservation of an equable animal temperature. By the decomposition of atmospheric air, caloric is evolved, and this caloric is taken up by the arterial blood, without its temperature being at all raised by the addition. When it passes to the veins, its capacity for caloric is diminished, as much as it had before been increased, in the lungs: the caloric therefore, which had been absorbed, is again given out; and this slow and constant evolution of caloric in the extreme vessels over the whole body, is the source of that uniform temperature which we have so much occasion to admire.

This same chemist has ascertained, that whenever an animal is placed in a medium the temperature of which is considerably high, the usual change of arterial into venous blood does not go on; consequently, no evolution of caloric will take place, and the animal heat will not rise much above the natural standard. How pleasing is it to contemplate the arrangements which the Deity has made for the preservation and felicity of his creatures, and to observe that he has provided for every possible exigency!

According to Lavoisier, a man generally consumes 32 ounces troy of oxygen gas in 24 hours; that is, the lungs separate this quantity of oxygen gas from the air which he respires in that time.

The blood, in passing through the lungs to take up oxygen gas, throws off charcoal; for there is a larger portion of carbonic acid gas thrown out in every respiration than could be furnished by the atmosphere.

mate is always inferior to the animal temperature*,

Lavoisier has shown that, in respiration, there is a constant combination of the oxygen of the atmosphere with the hydrogen and carbon of the blood. See Additional Notes, No. 9.

> " Thus LIFE discordant elements arrests,
> Rejects the *noxious*, and the *pure* digests;
> Combines with heat the fluctuating mass,
> And gives awhile solidity to gas." DARWIN.

See a good Memoir on Respiration, and the Production of animal Heat, by Armand Seguin, in the 6th volume of the Monthly Magazine, page 94: but this subject is treated more at large by Dr. Bostock, of Liverpool, than any other writer: to his work I would refer the reader.

[*] Those animals which do not breathe, such as fishes and insects, have a bodily temperature but little superior to the medium in which they live. The temperature of all animals is proportional to the quantity of air which they breathe in a given time. Man, quadrupeds, and the whale tribe, have a heart, and breathe through lungs; in consequence of which structure heat is evolved during the circulation of the blood. They are therefore called warm-blooded animals. In the severest winter, or in the coldest regions that man or any quadruped can inhabit, the temperature of the body is hardly a degree lower than in the warmest summer, or in the torrid zone. A thermometer with its bulb under the tongue, or buried in a wound in any fleshy part of the body, always indicates a heat of 97° or 98°, be the temperature of the air what it may.—(Skrimshire's Essays). This astonishing effect is produced by the decomposition of atmospheric air, as explained in the preceding notes. A postulatum has been assumed by some atheists, that the organs of the body have been formed by what they call *appetency*, i. e endeavour perpetuated, and imperceptibly working its effects through a long series of generations: but I would ask any man of common understanding, whether he would like to

clothes* are necessary to prevent the sudden escape of that heat from the surface of the body† which the lungs have separated from the atmosphere.

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assert that he believes this to have been the way in which the lungs acquired the faculty of decomposing atmospheric air; and that he believes that this hypothesis is sufficient to account for *the composition of this air,* which so exactly suits the operation of these lungs, and which contains that exact portion of caloric which the animal œconomy requires! It is worthy of remark, that cold-blooded animals, which are not furnished with this breathing apparatus, are so constituted that their temperature changes with every change of the temperature of the surrounding medium. Frogs have been absolutely frozen so as to chip like ice, and yet when carefully and gradually thawed have been completely reanimated.

* Clothes keep the body warm in consequence of the air which they infold within them; atmospheric air being a non-conductor of heat. It is on this principle that double windows preserve the warmth of apartments at an equable temperature. In like manner double lids for boilers, formed so as to hold a sheet of air, are found to be very effectual for preserving the heat of the liquor with a very small portion of fuel.

On this principle it is that light spongy substances, such as furs and down, afford the warmest clothing. Hence it is that the carpet which covers the earth in winter, is spread out by Nature with so light a hand, that it might hold an abundance of atmospheric air within its interstices, to preserve the warmth of those innumerable tribes of vegetables which it is destined to protect.

† We clothe ourselves with wool, because it is a bad conductor of heat and retards its escape from the body. The inhabitants of Russia clothe themselves in fur, because fur is

What becomes of the nitrogen which was combined with oxygen in atmospheric air?

The greatest part of the nitrogen is thrown out of the lungs at every respiration*; and being

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still a worse conductor of heat than wool. Sheep are natives of a temperate climate; but bears and ermine of the coldest. The provident care of the Creator is evidently conspicuous in this appointment, and discovers the same undeviating attention to the comfort of all his creatures; hence the clothing of animals in the torrid zone is hair, in the temperate zones wool, in the frigid thick fur.

The reason why we feel cold when naked, is owing to the property the air possesses of expanding by heat. For the air in contact with an animal body becoming expanded, is of course specifically lighter than the surrounding air; it therefore rises, and gives place to another stream of cold air; and this process continually going on, more caloric is taken from the body than can be spared without inconvenience.

* It is not simple nitrogen which is thrown out, but *nitrogen gas*; and it has been imagined, that when atmospheric air is decomposed by the lungs, part of the caloric remains combined with the nitrogen, to preserve it in the form of gas: but it is a curious fact, that nitrogen gas and carbonic acid gas, both which are thrown off in the act of respiration, have less capacity for caloric than any other gaseous substance. It is a general characteristic of the gases, that they absorb a large portion of caloric to preserve them in a gaseous form. Yet one of these gases has less capacity for caloric than many liquids, and the other (nitrogen gas) less capacity than even ice. Could any thing possibly have been better contrived for the preservation of that portion of caloric, which is necessary to keep up the animal temperature!

According to Mr. Davy, a small portion of nitrogen (viz.

somewhat lighter than atmospheric air, it rises into the atmosphere to await fresh combinations *.

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4 or 5 ounces in 24 hours) is absorbed by the blood, and furnishes the animal with one of its constituent parts. See Davy's Researches.

It may be remarked, that the interval which there is between every inspiration seems to have been designed, to allow time for the nitrogen gas which is thrown out of the lungs to mount in the air above the head, in order that a fresh portion of air might be taken in, and that the same air might not be repeatedly breathed. That this actually entered into the plan of the Divine mind, may be presumed from the levity which has been given to nitrogen gas, and which enables it to rise in atmospheric air.

* It may be observed that, if the specific gravity of the two constituent parts of atmospheric air had been reversed, the nitrogen thrown off by the respiration of men and animals would have perpetually occupied the lower regions of the atmosphere, and produced universal pestilence. Nitrogen gas is very little lighter than atmospheric air, but probably to that *little* the atmosphere owes the salubrity it possesses. How provident has the Almighty been, in thus foreseeing the operation of those laws which were designed to promote the welfare of every species of animated beings!

"A vessel of 1000 cubic inches will contain 315 troy grains of common air; but it will contain 335 of oxygen gas, and only 297 of nitrogen gas." Dr. Black's Lectures, vol. ii. 109.

From the experiments of some aëronauts, it appears that the air in the upper regions is more impure than that nearer the earth; which is probably owing to the greater levity of nitrogen gas, or to the effects of vegetation on the lower parts of the atmosphere.

What provision has nature made for restoring the vast quantity of oxygen which respiration and combustion are perpetually taking from the atmosphere?

The leaves* of trees and other vegetables give out during the day a large portion of oxygen gas†, which, uniting with the nitrogen gas thrown off by animal respiration, keeps up the equilibrium, and preserves the salubrity of the atmosphere.

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* The *upper* side of the leaf is the organ of respiration; hence some vegetables (as they give out oxygen only in the day) close the upper surfaces of their leaves during the night. The multiplicity of the leaves of trees, &c. shows the *importance* of transpiration to a vegetable.

To obtain oxygen gas from the leaves of plants, fill a glass bell with water, introduce leaves under it, and place the bell inverted in a flat dish of water. Expose the apparatus to the rays of the sun, and very pure oxygen gas will be disengaged, which will displace the water in the jar, and occupy its place. A sprig of mint, corked up with a small portion of *foul air* and placed in the light, renders it again capable of supporting life. The plant purifies what the animal had poisoned.

Hales found that a sun-flower, three feet high, transpired in 12 hours seventeen times as much as a man.

† Thus while the vegetable tribes inhale
The limpid water from the parent vale,
Their vegetating organs decompose
The salutary compound as it flows,
And, by affinities unknown, dispart
The subtle hydrogen, with chemic art,

Is this perpetual renovation of the atmosphere owing to a fortunate concurrence of circumstances, or is it the effect of design and contrivance?

When we recollect the various processes of nature and art, which concur with respiration and combustion in depriving the atmosphere of its oxygen; and that, notwithstanding, the atmosphere uniformly contains every where the same proportion of this gaseous substance, we can attribute the renovation to nothing but design, and perceive in it a proof that the laws of nature must be referred, not to blind chance,

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To blend it with the carbon of the soil,
And form bitumen, resin, wax, or oil[a]:
The free'd caloric bursts the expanding mass,
And swells the nascent oxygen to gas;
Which, from its inmost cells, each leaflet pours
In vital currents through its myriad pores,
To renovate the air, by tempests hurl'd
From pole to pole, around a freshen'd world.

All the oxygen is not given out by plants; part must be retained to form the sugar and acids which are found in vegetables. Mr. Cruickshank has shown by experiment, that oxygen is absolutely necessary for the conversion of mucilage into sugar. (Rollo on Diabetes.) Plants also absorb nitrogen from the atmosphere with avidity; and this is another means of keeping up the standard purity of atmospheric air.

[a] See the eleventh question of chapter iv.

but to unerring intelligence combined with infinite goodness*.

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[*] All kinds of vegetables, when assisted by the rays of the sun, have the power of decomposing water; during which decomposition the hydrogen is absorbed, and goes to the formation of oil and resin in the vegetable; while the oxygen combines with part of the caloric received from the sun, and is given out in the form of oxygen gas; so that this *one operation* of nature gives nourishment and provides materials of growth to the vegetable creation, and at the same time renovates the vital principle in the atmosphere. Nothing short of consummate wisdom could have conceived any thing half so beautiful in design, or extensively and superlatively useful in effect. See Additional Notes, No. 10 and 18.

CHAP. III.

OF CALORIC.

WHAT is heat?

Heat is the well-known sensation occasioned by bodies of a superior temperature[*].

What name is given to the matter of heat?

Chemists have agreed to call the matter of heat *caloric*[†], in order to distinguish it from the sensation which this matter produces[‡].

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[*] The sensation of heat and cold arises from the tendency which caloric has to diffuse itself equally amongst all substances that come in contact with it. If the hand be put upon a hot body, part of the caloric leaves the hot body and enters the hand: this produces the sensation of *heat*. On the contrary, if the hand be put upon a cold body, part of the caloric contained in the hand leaves the hand to unite with the cold body: this produces the sensation of *cold*.

For the best methods of producing artificial cold, consult Mr. Walker's papers in the Philosophical Transactions for 1795 and for 1801.

[†] In answer to the question, What is the *cause* of caloric? it may be necessary to state, that philosophers have differed in their opinions on this subject. Some have considered it merely the consequence of a peculiar motion among the particles of bodies, and that it has no existence independent of motion, any more than sound has. Others have supposed that it is really a distinct substance, which exists independent of every other. The latter is the opinion of modern chemists.

[‡] In order to give precision to chemical language, it was

What are the uses of caloric[*]*?*

Caloric is every where indispensable to the existence of man. "It is with fire that, in every country, he prepares his food, that he dissolves metals, vitrifies rocks, hardens clay, softens iron, and gives to all the productions of the earth the forms and combinations which his necessities require."

What are the sources of caloric?

There are six sources from whence we procure caloric; viz. from the sun's rays, by combustion, by percussion, by friction, by the mixture of different substances[†], and by means of electricity and galvanism.

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necessary to find a term to distinguish the matter of heat from its effect; for, whenever caloric becomes fixed in a body, it loses its property of affording heat. Nothing can be more evident than that caloric may exist in many substances, without producing any of the effects which arise from the agency of fire.

[*] Many of the uses of fire will immediately occur to every individual, whenever the importance of this subtil fluid is alluded to; though perhaps the wisdom of the Deity, in giving the use of it to man only, has not been often noticed. Why has this powerful agent been solely intrusted to man? Why was every fowl of heaven, and every beast of the field, impressed with an unconquerable dread of approaching it? If it were at the disposal of animals, which of our possessions, or even of our lives, would be safe for a single moment!

[†] These are the chief sources of caloric with which we are acquainted; but there are instances of *spontaneous* combustion on record, which are unaccountable. The most remarkable case that I have seen, is related in the Philosophical Magazine,

Which of these is the principal source of caloric?

The sun is the first source which furnishes the earth with a regular supply*, and renders it capable of supporting the animal and vegetable creations†.

How is caloric furnished by combustion?

The oxygen gas of the atmosphere is *decom-*

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vol. xvi. 92. See also an interesting memoir on this subject, vol. xviii. 346.

Perhaps *compression* might with propriety be added to this list. See an account of Mr. Biot's Experiment, in a note, chap. iv; and that of the effects of the sudden compression of atmospheric air in the chapter on *combustion*.

* Caloric comes to us from the sun at the rate of 200,000 miles in a second of time; but Dr. Herschel has proved, that the solar rays which produce heat are distinct from those which illuminate and produce vision.

Such investigations have a tendency to impress us with the most sublime ideas of the œconomy of the universe, and to convince us of the infinite resources of its Divine Author.

> "Great source of day! for ever pouring wide,
> From world to world, the vital ocean round,
> On Nature write, with every beam, His praise."

† According to the laws of nature, animal and vegetable life are both very much influenced by the temperature in which they exist; we therefore find different kinds of vegetables, and a different race of animals, appropriated to the different climates of the earth.

That caloric is as necessary for the support of vegetable as it is for that of animal life, may be proved by direct experiment. If in the midst of winter a hole be bored in a tree, and a thermometer put into it, it will be seen that the tree is many degrees warmer than the atmosphere. Walker, vol. i. 103.

posed by combustion; and caloric, one of its component parts, is set at liberty[*].

How is caloric produced by percussion?

The heat produced by percussion is generally occasioned by the *compression* of the particles of the body, which compression forces out a portion of its latent caloric[†].

How is caloric produced by friction?

It is not known how friction produces caloric[‡],

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[*] We are indebted to Lavoisier for the discovery that caloric is disengaged from atmospheric air by combustion: it was he who pointed this out as a general law of nature, "that in all cases of combustion, oxygen combines with the combustible, during the act of combustion." For a further explanation of this phænomenon consult the chapter on *combustion.*

[†] As evaporation produces cold, condensation always produces heat: that is, caloric is always evolved from those bodies which have undergone any degree of condensation. In the one case caloric is absorbed, in the other it is set at liberty.

By the collision of flint and steel so much caloric is disengaged, that the metallic particles which are struck off are actually melted thereby. This is evident, from their being always found in a spherical form. See note †, page 93.

[‡] Mr. Thomas Wedgwood has shown that this subject has never yet been explained. He took a piece of common window-glass, and held the edge of it against the edge of a revolving grit-stone, and the part in contact with the stone became red hot, and threw off hot particles which fired gunpowder. The stone and the glass being both incombustible substances, it remains to be explained how caloric was produced. Philosophical Transactions for 1792.

The original inhabitants of the New World, throughout the whole extent from Patagonia to Greenland, procured fire by unless we suppose it to be a succession of percussions; or it is probably to the agency of electricity* or galvanism alone we must ascribe the cause.

In what way can heat be produced by means of electricity or galvanism?

By the discharge of an electrical battery †, or by the galvanic apparatus‡, a more intense degree of caloric may be obtained than by any other means whatever.

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rubbing pieces of hard wood against other very dry pieces, till they emitted sparks, or kindled into a flame. Some of the people to the north of California had the method of inserting a kind of pivot in the hole of a very thick plank, and by its circular friction produced the same effect. Dr. Rees's Cyclopædia.

Instances have occurred, where whole forests have been burnt down, by fires kindled from the violent friction of the branches against each other by the wind.

* For the reasons on which this supposition is grounded consult Dr. Thomson, vol. i. 445.

† By means of an electrical battery metals may be suddenly fused, and gases united, which we are unable to combine by any other mode.

‡ If fine metallic wire be made part of a powerful galvanic circle, it will be melted in an instant, and give out the most beautiful coruscations of light, of various colours, according to the nature of the metal employed. In like manner gold and silver leaf, when submitted to galvanic action, burn with the greatest splendour, and afford spectacles extremely beautiful. If a piece of charcoal, from hard wood, be inflamed by galvanism, the light produced seems to vie with that of the sun, being too intense for the eye to endure.

How is caloric produced by mixture?

When heat is produced by the mixture of two or more substances, it is owing to the fluid part of the mixture taking a more solid form*; for neither water nor any other fluid can acquire an increase of density without giving out a portion of its latent caloric†.

With Mr. Pepys's apparatus, charcoal has been deflagrated by the galvanic power, after passing through 16 persons with wetted hands joined.

[*] Whenever two gases or liquids unite *chemically*, the compound has greater density than the mean density. Thus the vapour of water, at the heat of ebullition, occupies much less space than the hydrogen gas and oxygen gas, which compose it, would have occupied at the same temperature. Nitrous gas has a specific gravity greater than that of the simple mixture of its two elements: it is the same with ammoniacal gas; and this latter, though its elements are already greatly condensed, experiences a new condensation when it combines with muriatic acid gas; which is even so considerable, that both take a solid form. Berthollet.

[†] Sulphuric acid and water experience this condensation by mixture, which is proved both by the measure of the fluids, before and afterwards, and by the heat that is evolved. If four parts of the former be mixed with one of the latter, the mixed fluids will quickly acquire a temperature higher than that of boiling water. It is necessary to be cautious in making this experiment, and always to pour the *acid* gradually into the water.

If iron filings and sulphur be mixed into a paste with water, a sulphuret of iron will be formed, which decomposes the water and absorbs oxygen so rapidly that the mixture takes fire, even though it be buried under ground.

Mixture does not uniformly produce heat. The mixture of

You speak of latent *caloric; is there any difference in the nature of caloric?*

No: we have reason to believe that caloric is always uniform in its nature; but this term is necessary, because there exist in all bodies two portions of caloric, very distinct from each other[*].

How are these two portions of caloric distinguished?

The one is called *sensible* heat, or free caloric; the other *latent* heat, or combined caloric[†].

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some substances produces an intense cold. But the cause of both effects is easily explained. Whenever substances become more condensed by mixture, heat is evolved; when they expand, cold is produced; or, in other words, the compound has a greater or less capacity for caloric than the separate ingredients. The mixture of muriate of lime and ice produces the greatest degree of cold yet known.

[*] How the same substance may exist in a body in two distinct states, may easily be explained by a piece of common bread which has been dipped in water. This bread will contain two portions of water very distinct; one of them was in a state of combination, and formed a constituent part of the bread; the other is only interposed between the particles of the bread, and may again be forced out by pressure.

[†] The difference which there is in the effects of caloric, in the two states in which caloric exists, may be shown by a variety of experiments. Wrought iron, though quite cold, contains a large portion of *latent* caloric; and if it be briskly hammered for some time on an anvil, it will become red hot by the action of this species of caloric, which by the percussion of hammering is now evolved and forced out as *sensible* heat.

What do you mean by free or sensible caloric?

Sensible caloric is the matter of heat disengaged from other bodies, or, if united, not *chemically* united with them[*].

What is latent caloric?

Latent caloric is that portion of the matter of heat which makes no sensible addition to the temperature of the bodies in which it exists[†]

While chemically combined with the iron, it only tended to give it malleability and ductility; but when converted to free caloric, it operates with as much activity as though it had never existed in a latent state.

If a little sulphuric acid be mixed with about an ounce of nitrous acid, and the mixture be poured into oil of turpentine, the whole will burst into flame. This is owing to the compound having less capacity for caloric than these separate fluids; consequently a part of their combined caloric is liberated, and produces the inflammation. The phial containing the acids should be fixed to a rod, and its contents poured at once upon the oil in a cup, placed in the open air, or under a large chimney, to prevent any accident from the sudden combustion.

The reverse of this may be shown by hanging a pan of snow over a large fire. The snow will receive a great accession of caloric from the fire without being at all sensibly warmer. The caloric as it enters becomes chemically combined, and the fire will not in the least alter its temperature, till the whole becomes fluid.

[*] Some writers have called the matter of heat when in this state *interposed* caloric.

[†] We owe to Dr. Black the discovery of *latent* heat. The train of thought and series of experiments which convinced him of this fact may be seen amply detailed in the preface to his lectures, 34 and following pages. " By this discovery we

What substances contain latent caloric?

Caloric in a latent state exists in all substances that we are acquainted with*.

Do all substances contain the same quantity of latent caloric?

No: caloric combines† with different substances in different proportions.

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now see (as his editor expresses it) heat susceptible of fixation—of being accumulated in bodies, and, as it were, laid by till we have occasion for it; and are as certain of getting the stored-up heat, as we are certain of getting out of our drawers the things we laid up in them."—Black's Lectures, by Robison. He might have added, that whenever caloric quits its latent state, how long soever it may have lain dormant and inactive, it always resumes its proper qualities and character, and affects the thermometer and the sense of feeling as if it had never been latent.

* Caloric pervades all bodies: this is not the case with any other substance we know of—not even light.

Caloric lies hid in every thing around us. The Creator knew the continual need we should have of this substance, and he has accordingly endowed it with the property of taking up its resting-place and of combining with *all* matter, however diversified may be its nature or properties. Caloric is a substance which we are ever in want of; it is therefore deposited on every side, and is ready for every exigency. Various and multiplied as are the means which have been chosen for the promotion of the general good, they are all wise and beneficent, all fully adequate to the end for which they were designed.

† Caloric as it penetrates bodies frequently forms a chemical combination with them, and becomes essential to their composition. This is always the case when a solid is converted to a liquid, or when a liquid passes to a gaseous state. But if

What language do chemists make use of to express the difference in this respect?

One body is said to have a greater *capacity* for caloric than another*.

Is this capacity for caloric uniformly the same in the same bodies?

Yes: the same bodies have at all times the same capacity for caloric, unless some change takes place in the *state*† of those bodies.

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caloric be superadded to a body when it is in a state of saturation, it merely traverses its surface, and passes from it, in the form of sensible heat, to some of the adjacent bodies.

It is the opinion of some chemists, that the absorption of caloric, which accompanies liquefaction and vaporisation, is owing not to its entering into chemical combination, but to the enlarged capacity which the body acquires by a change of form. To those who wish to investigate this subject I would recommend the perusal of Murray's Chemistry, vol. i. 409, &c. See also Additional Notes, No. 36.

* The propriety of this term may be shown to a pupil by dipping a lock of wool and a piece of sponge in water, and directing him to observe how much more water the sponge is capable of taking up than the wool. Hence sponge may be said to have a greater *capacity* for water than wool has.

† The nature of the combination of bodies with caloric was first placed in a clear light by Dr. Black. He discovered that all matter is subject to the following law, viz. that "whenever a body changes its state, it either combines with, or separates from, caloric."

This subject is treated with great perspicuity by Dr. Thomson in the first vol. of his System of Chemistry, to which I refer those who wish to investigate it.

If muriate of ammonia be dissolved in hot water, the tem-

Can you adduce instances of a change of this kind?

When gaseous substances become liquid, or liquid substances become solid, they lose in a

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perature of the water will be found to be much lowered by the solution of the salt. When the salt takes again a solid form by crystallization, it will part with the caloric which it combined with in the act of solution, and a rise of temperature will be the consequence. The cold which is produced by the solution of this and other crystallized salts, is owing no doubt to the water, which was combined with them in a state of solidity, suddenly taking a liquid form, and absorbing caloric to preserve it in a state of fluidity.

If when the air is at 22° we expose to it a quantity of water in a tall glass, with a thermometer in it and covered, the water gradually cools down to 22° without freezing, though 10° below the freezing point. Things being in this situation, if the water be shaken, part of it instantly freezes into a spongy mass, and the temperature of the whole instantly rises to the freezing point; so that the water has acquired 10° of caloric in an instant. Now whence came these 10°? Is it not evident that it must come from that part of the water which was frozen, and consequently that water in the act of freezing gives out caloric?—Dr. Black. Water in a solid state has less capacity for caloric, than it has when in a state of fluidity, although it then occupies a greater space.

The evolution of caloric which is occasioned by the combination of the condensible gases with water during several kinds of distillation, must be very familiar to those who have been accustomed to superintend chemical operations. In some cases, this evolution of caloric is so considerable, as to raise ice-cold water almost to the state of ebullition. But there is a singular exception in the combination of oxygenized muriatic acid gas with a solution of potass. Whenever I have conducted this great measure their capacity for caloric: accordingly, when solid bodies become liquid or gaseous, their capacity for caloric is proportionately increased*.

How does this property of bodies operate?

Whenever a body has its capacity for caloric thus increased, it requires a larger portion of the matter of heat to raise it to a given tempera-

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operation, I have not failed to notice, that though a large quantity of gas is absorbed by the liquid, very little caloric is evolved. The caloric doubtless forms a component part of the salt, and contributes to those powerful effects which are produced whenever this salt is deflagrated with inflammable substances.

[*] The freezing of water, and the cooling of melted lead, may be adduced as familiar examples of the former; and the absorption of caloric in the melting of salts will sufficiently exemplify the latter. By the solution of some salts water may be deprived of so large a portion of its caloric as to be frozen in the midst of summer. An account of several cheap and powerful frigorific mixtures may be seen in the Philos. Trans. for 1787, 1788, 1789. See also Watson's Chemical Essays, vol. iii. 139. The heat which is given out during the slaking of quicklime, escapes from the water in consequence of its changing from a liquid to a solid form by its union with the lime. The same effect is produced in making butter. When the cream changes from a fluid to a solid, a considerable degree of heat is produced.

Oxygenized muriatic acid gas becomes a *liquid* at a temperature somewhat below 40°, and at 32° forms *solid* crystals. Ammoniacal gas condenses into a liquid at —45°.

When water is poured upon dry pulverized plaster of Paris, ture, than another body does which has a less capacity for caloric*.

Can you exemplify this curious property of matter?

If equal quantities, by weight, of water and mercury, cooled down to the same point, be afterwards separately heated to the heat of boiling water, the water will be found to have required more than three times the quantity of caloric that the mercury did to bring it to that temperature†.

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in order to form cornices for rooms, great heat is produced by the mixture. This is owing to the water giving out its caloric of fluidity as it becomes solidified in the plaster.

Whenever caloric becomes active it produces heat; whenever it passes into a latent state it produces cold.

[*] The difference in the capacity which different bodies have for caloric, is owing to one substance having a chemical affinity for caloric superior to that of another. See this fully explained by Mr. William Henry in the fifth volume of the Manchester Memoirs.

[†] This property may be shown more readily by the following experiments:—Take 1 lb. of water at 100°, and mix it with 1 lb. of water heated to 200°, the mixture will be found to give the exact mean temperature of 150°; but 1 lb. of mercury at 100°, and 1 lb. of water at 200°, will produce a heat much higher than the mean temperature: mercury has not therefore so great a *capacity* for caloric as water.

A metal plunged into an equal weight of water of a higher temperature, gains more degrees of thermometric heat than the water loses; and this takes place, in different proportions, for each species of metal. Berthollet.

Whenever two different kinds of substances of different temperatures are mixed, the capacity of each for caloric may be

What term is made use of to denote the quantity of caloric thus required?

The portion of caloric necessary to raise a body to any given temperature is called the *specific* caloric of that body*.

Is there any method of ascertaining the specific caloric of different bodies, and comparing the relative capacity of each for caloric?

An instrument called a *calorimeter*† is used for this purpose. The substances to be tried are

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known by observing the temperature of the mixture; for the capacity of each will be in the inverse ratio of the change of temperature. But it is necessary, in order to justify this calculation, as Fourcroy has remarked, that the bodies themselves should not act chemically upon each other; and it is also necessary to prevent a portion of their caloric from being carried off by the vessels in which the experiment is made.

* This term is always used in a *comparative* sense, expressive of the relative portions of caloric contained in equal weights or measures of different bodies at the same temperature, or the comparative quantity of caloric which can produce the same effect. Thus, if the specific caloric of mercury be said to be 1, that of water may be said to be 3, as noted in an experiment just related.

† The calorimeter was first suggested by M. Laplace, and contrived by Lavoisier. A drawing of the machine, with an accurate description of it, may be seen in Lavoisier's Elements. Though this instrument be capable of measuring what is called the *specific* caloric of bodies, no method has yet been discovered of ascertaining the *absolute* quantity which bodies contain. It is therefore unknown at what point a thermometer would stand, if it were plunged into a substance entirely deprived of

heated to the same temperature, and then placed in this machine surrounded with ice[*]. By observing how much ice each of them melts in cooling down to a given point, the specific caloric which each of them contained is determined[†].

What do you call the instrument which is in common use to measure the temperature of bodies?

It is called a thermometer[‡]. It consists of a glass tube containing a portion of mercury, with

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caloric. According to the experiments and calculations of Crawford, Irvine and others, the real zero is, probably, at least 1200 degrees below the freezing point of water.

[*] Ice has the property of absorbing all the caloric with which it comes in contact, and communicates no part of it to the surrounding bodies till the whole of the ice is melted; therefore the specific caloric of bodies may easily be calculated by its means.

[†] Sir Isaac Newton talks of boiling water being three times as hot as the blood in the human body. He imagined the freezing point to be the real zero, below which there was no heat. Later experiments have shown that substances may be cooled many degrees below the freezing point on Fahrenheit's scale. At Kamtschatka the atmosphere has been known to be 40 degrees colder than the zero of our thermometers.

[‡] The thermometer was invented by Sanctorius, an Italian physician, about the beginning of the 17th century; but it was improved, and rendered useful, by Mr. Boyle and Sir Isaac Newton.

Thermometers are made by putting mercury into small glass tubes with bulbs, and heating these bulbs till the mercury boils.

a graduated plate annexed to it. The tube is hermetically sealed, to preserve the metal from the pressure of the atmosphere*.

Do you understand how a thermometer is affected by the temperature of bodies?

When a thermometer is brought in contact with any substance, the mercury expands or contracts till it acquires the same temperature; and

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This ebullition exhausts the tubes of air, and they are hermetically sealed while the mercury is boiling; which preserves the vacuum. They are afterwards graduated by a correct scale.

Thermometers filled with alcohol are useful for ascertaining very low temperatures in which mercury would be frozen—as alcohol preserves its fluidity in the most intense colds that have ever been observed.

For very delicate experiments *air* thermometers are used, in which, as the air is expanded or contracted, a coloured liquor is made to fall or rise, which marks the degree of expansion, and consequently the variation of temperature. They are called thermoscopes.

* Mercury, though a metal, has so great an attraction for caloric, that it absorbs sufficient to keep it in a fluid state in the common heat of the atmosphere. Owing to this affinity for caloric, it expands very readily by every addition of the matter of heat. It is also equally affected by equal increments of heat at every temperature between its freezing and boiling points; which is not the case with some other fluids, such as water, spirit, &c.: hence it is the most proper substance for thermometers.

To measure the degrees of heat in high temperatures, Mr. Wedgwood contrived a very useful instrument which he called a pyrometer, including a range of nearly 32,000 degrees of Fahrenheit; a description of which may be seen in the 72d the height at which the mercury then stands in the tube, indicates the exact temperature of the substance to which it has been applied*.

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volume of the Philosophical Transactions. Since Mr. Wedgwood's death, the method of making the pieces of clay for these pyrometers has been lost.

[*] Fahrenheit's thermometer is universally used in this kingdom. In it the range between the freezing and boiling points of water is divided into 180°; and as the greatest possible degree of cold was supposed to be that produced by mixing snow and muriate of soda, that was made the zero: thus the freezing point became 32°, and the boiling point 212°.

The centigrade thermometer of France places the zero at the freezing point, and divides the range between it and the boiling point into 100°. This has long been used in Sweden under the name of Celsius's thermometer.

Reaumur's thermometer, which was formerly used in France, divides the space between the freezing and boiling of water into 80°, and places the zero, like the centigrade thermometer, at the freezing point.

De Lisle's thermometer is used in Russia. The graduation begins at the boiling point, and increases towards the freezing point. The boiling point is marked 0, and the freezing point 150°.

In Wedgwood's pyrometer the zero corresponds with 1077° of Fahrenheit's, each degree of which is equal to 130° of Fahrenheit. Therefore 180° F. = 100° C. = 80° R. = 150° D. L. = $\frac{18}{13}$ W.

For an easy method of reducing the degrees of one thermometer to the scale of another, consult Dr. Duncan's Elements of Pharmacy; or Lavoisier's Elements of Chemistry, p. 560, fourth edition. See a table of temperatures, according to the different thermometers, at the end of this volume, which will enable a person to form a tolerably idea of the difference there is in the scales of each.

Will the thermometer show the quantity of caloric in all bodies[*]*?*

No: it will not show that portion which is latent, or chemically combined with any body: for instance, fluids require a certain portion of caloric to keep them in a state of fluidity; which portion is not indicated by the thermometer[†].

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[*] The property which we call the temperature of bodies does not show the measure of their caloric, but merely the degree of dilatation, which the caloric they contain in a disengaged state is capable of producing in the substance of which the thermometers are formed.

[†] Every substance requires its own quantity of caloric to raise it to a given temperature; but when raised to that temperature, every *further* addition of caloric is precisely shown by the thermometer. See Additional Notes, No. 4 and 36.

If a quantity of snow be placed in a bason before a fire, and a thermometer be plunged in it, the thermometer will stand at 32°: if the thermometer be removed, and the snow suffered to remain before the fire some time longer, and then tried by the thermometer, it will still indicate the same temperature, though it has all along been receiving an accession of caloric; but the moment that the *whole* of the snow is melted the thermometer will begin to rise. In like manner, suppose a piece of ice cooled 20° below the freezing point be exposed to a hot fire with a thermometer stuck in it; the thermometer will rise very uniformly till it comes to the freezing point 32°, and there make a full stop till the ice is all liquefied, as though the fire had lost its faculty of heating: but the instant that all the ice is melted the thermometer will begin to rise again, and will continue to rise gradually till the water becomes heated to 212°, the boiling point. See Additional Notes, No. 4. These experiments show that the heat which snow and ice receive while

Is the thermometer, then, of no use in ascertaining the temperature of fluids?

Yes: fluids operate upon the thermometer in the same manner as solids; for, whatever sensible caloric be contained in any liquid, that portion is accurately shown by the thermometer*.

What do you call that portion of caloric which is a necessary part of fluids?

It is called the caloric of fluidity; but diffe-

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while melting is necessary to give them fluidity, though it does not increase their temperature; and that ice contains much less absolute caloric than water at the same temperature. Were this not the case, all cold countries would be subject to dreadful inundations; for, whenever the atmosphere became warmer than 32° the ice and snow would be melted *in an instant*, and the sudden deluge of water would sweep down every thing before it. It is pleasing to observe how careful the great Author of nature hath been in providing for every exigency. To this goodness every clime and every season bear testimony.

> "The tokens of HIS friendly care
> Open, and crown, and close the year."

* Nature is uniform in all her results; for, if we plunge a thermometer ever so often into boiling water, it will always stand at the same point, provided the pressure of the atmosphere be the same. Melting snow will always show the same degree upon the thermometer, in whatever state the atmosphere may be. See Additional Notes, No. 36.

> "In tubes of glass mercurial columns rise
> Or sink, obedient to th' incumbent skies;
> Or, as they touch the figur'd scale, repeat
> The nice gradations of circumfluent heat."
>
> DARWIN.

rent fluids require different portions of it to preserve them in the state of fluids*.

What are the effects of caloric upon bodies?

The *general* effects of caloric are to increase the bulk of the substances with which it unites,

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* This may be made evident by the following easy experiments:—If four parts of sulphuric acid and one part of ice, both at the temperature of 32°, be mixed together, the ice melts instantly, and the temperature of the mixture rises to 212°, the heat of boiling water. But if four parts of ice and one of the same kind of acid at 32° be mixed, the temperature sinks to about —4°. In the first of these experiments, as the ice and acid combine, they become more dense than their *mean* density; consequently, they both give out a part of their caloric of fluidity, and retain only the caloric of fluidity which is necessary for the new compound. In the other case, the ice, assuming a liquid form, requires a large dose of caloric to give it fluidity; and the sudden fall of the thermometer is owing to the suddenness with which the ice absorbs the caloric from the acid, and which it requires before it can take a liquid form. See note to the third question of chap. iv.

According to Dr. Irvine, the caloric of fluidity of

Water	is -	140°
Spermaceti	- -	145
Bees wax	- -	175
Tin	- - -	500

Bishop Watson has remarked, that nitrous acid mixed with snow water excites a very great degree of heat, but when mixed with snow produces the greatest cold that has ever yet been observed. *Chem. Essays, vol. iii.* 142.

Our power of producing cold is at present very limited when compared with that of exciting heat. No one that we read of has ever yet been able to sink the temperature of any substance below —90° of Fahrenheit, or 122 below the freezing point of and to render them specifically lighter than they were before*; but in whatever quantity it is accumulated in bodies, it never adds to their absolute weight.

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water; but Mr. Wedgwood constructed an air furnace in which he raised a heat equal to 185 degrees of his pyrometer, or 25.127° of Fahrenheit; and by means of oxygen gas, more intense heats than even this have been produced.

[*] In order to be convinced that solids increase in bulk by combination with caloric, procure a piece of iron wire, of an exact length, to slip within a ring, or within some metallic box; then if the wire be heated it will be found increased in length so as not to pass through the ring or box.

From the experiments of General Roy, in the 75th volume of the Philosophical Transactions, it appears that the expansion of a steel pendulum of a clock is such, that every four degrees of the thermometer will cause a variation of a second per day; and that the difference between the going of a clock in summer and winter will be about six seconds per day, or one minute in ten days, owing to the metallic pendulum varying in length with every change of temperature. A knowledge of this circumstance gave rise to Harrison's self-regulating time-piece, which, by the different expansion of *different* metals, accommodates its movements to every change of season or climate.

The expansion which heat gives to liquids may be shown by that of the spirits in a spirit thermometer: or fill a Florence flask with water to about the middle of the neck, mark the place to which it rises, and then immerse it in boiling water; when it will be seen to expand in the glass till it nearly runs over the neck of the flask.

The effect of heat on atmospheric air has been shown in page 53. The converse of this (viz. that the denser bodies are, the less caloric they contain,) may be exemplified thus:—Add one measure of water to four measures of sulphuric acid, and

What are the particular effects of caloric on bodies?

It favours the solution of salts[*], and promotes the union of many substances[†]. In other cases it serves to separate bodies already united[‡]; so

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the temperature will rise to 300°, which is 88° above boiling water. If the mixture be now measured it will be found to measure less than it did; consequently it must have become much denser than the medium of the two separate liquors. If 28 measures of water be mixed with 4 measures of sulphuric acid, only 29 measures of mixture will be produced instead of 32.

The best collection of facts respecting the expansion of *wood* by heat, will be found in a memoir by Dr. Rittenhouse, in the Transactions of the American Philosophical Society.

Some bodies are much more dilatable by heat than others; thus iron is more dilatable than wood, and wood is more dilatable than a stone. Of the metals, platina dilates the least, and lead and zinc the most, by increase of temperature.

[*] Put two ounces of sulphate of soda (Glauber's salt), in powder, into a tea-cup of cold water, stirring them together, and the water will dissolve only a portion of it; but if heat be applied, the whole will be dissolved. If the liquor be left to cool, the salt will be seen to shoot into crystals. This little experiment will have its use as an example of crystallization.

[†] Sulphur and mercury may be mixed; but if caloric be added, they combine so intimately as to form vermilion. Charcoal seems to have no attraction for oxygen in the atmospheric temperature, but if heated it unites to it with great eagerness.

[‡] This is the case in distillation, whereby the most subtil parts of a compound body are dissolved by caloric, and separated from the mass in the state of gas or vapour. Every kind of distillation may be performed in a common retort, with

that in the hands of chemists it is the most useful and powerful agent we are acquainted with*.

Can you recollect any other effect that caloric has upon bodies?

It is the cause of fluidity in all substances which are capable of becoming fluid †, from the heaviest metal to the lightest gas ‡.

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common receivers attached to it. For strong heats, Wedgwood's retorts are preferable to glass. Some important directions for the conducting of different kinds of distillation may be seen in a paper of the thirteenth volume of the Repertory of Arts, giving a very particular account of the management of these processes at Petersburgh.

Caloric also promotes the decomposition of bodies, by reason of its counteracting the attraction of cohesion which exists in all bodies.

[*] For a more particular explanation of the effects of caloric in chemical processes, consult the article *Repulsion* in chapter xiii.

Mr. Watt mentions a strong analogy between *solution* and *fusion:* thus ice and soda have no more action on each other than soda and silex; but raise the temperature of the ice, and it unites to the soda. A sufficient increase of temperature will unite the silex also to the soda. Potass and silex if mixed have no action on each other; but if submitted to a great heat the potass melts, and attracts the silex, which melts with it into a substance that may be dissolved in water; or, if the silex be in proper proportion, the compound will be glass.

It is owing to the effect of caloric in promoting solutions, that sea-water in the torrid zone contains more salt than sea-water in the temperate and frigid zones.

[†] Let it be remembered that all fluids are formed from solids by an addition of caloric; and that, by abstracting this caloric, solids would be reproduced.

[‡] For an account of the expansion of gaseous bodies by heat,

How does caloric act upon hard bodies to convert them into fluids?

It insinuates itself among their particles, and separates them from each other[*]. Thus ice is converted into water, and by a further portion of caloric into steam[†].

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see a detail of Mr. Dalton's experiments in the 5th volume of the Manchester Memoirs, p. 595; and in several papers in Nicholson's Journal. For a method of estimating the changes of volume in gases, consult Mr. Davy's memoir in the Journals of the Royal Institution.

The expansion of volatile bodies by heat may be shown by the following experiment: Put a little ether into a small retort, tie a bladder to the beak of it, and hold the retort over a lamp. The ether will quickly boil, and the gas which arises from it will soon occupy the bladder and distend it to its full size. If the bladder be then held in water, the gas will be condensed by the loss of its heat, and the bladder will collapse. In order for this experiment to succeed, it is necessary previously to warm the bladder to 80 or 90 degrees, to prevent the gas from being condensed in the first instance.

[*] From this general effect upon bodies, caloric has been considered as the only agent in insensible repulsion. It has been called the *repulsive power*, which constantly acts in opposition to the power of attraction, or chemical affinity.

[†] Though the temperature of steam be no more than that of boiling water, or 212°, yet it has been demonstrated by some very ingenious experiments of Mr. Watt, that it contains near 1000° more caloric; and this keeps it in the form of steam. Here the caloric must be in a state of chemical combination with the water, or it would be indicated by the thermometer. It is owing to this principle (viz. the necessity of a large quantity of caloric being combined with fluids, to convert them into vapour or gas,) that profuse perspiration is so cooling to labour-

How are those substances distinguished which are capable of being thus rendered fluid by caloric?

We have reason to believe that every solid substance on the face of the earth might be converted to a fluid, or even a gas, were it submitted to the action of a very high temperature in peculiar circumstances*.

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ing men, and that all evaporation produces cold. A person might be frozen to death in summer by being repeatedly sprinkled with ether. See Additional Notes, No. 36.

In Spain this principle is so well understood, that every family is provided with an utensil for cooling water or wine by *evaporation*. It is merely a piece of very porous earthenware, which they fill with the water; and as a small quantity is perpetually oozing through every part of the vessel, a constant evaporation from the outside is kept up, which cools the water within. The vessels are called acarrazas, and may now be had at the china-shops in London.

"In India and China the wealthy have their rooms open on all sides, the roof being supported on pillars, and the intervals hung with curtains. Servants without doors scatter water on these curtains continually; its evaporation absorbs a vast deal of heat, and makes the apartments cool and refreshing." Dr. Black.

* The late experiments of Sir James Hall have thrown considerable light upon this subject. It appears that many substances which were deemed infusible, were so only in consequence of the decomposition they suffered in the usual way in which they were submitted to the action of caloric; but by means of a pressure sufficiently strong to prevent the escape of the volatile parts of the substance, such as the carbonic acid from calcareous earth, &c., he succeeded in fusing limestone,

You say the sun is the great source of caloric: how is caloric transmitted from the sun to us?

Caloric is transmitted to us accompanied with light: both are perpetually thrown off from the sun, with astonishing velocity, in every direction*.

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chalk, marble, and even common coal. These effects were produced, in several instances, at a temperature much lower than would have been imagined. See Sir James's very interesting Papers in the Edinburgh Philosophical Transactions.

* Since the discoveries of Dr. Herschel, we have reason to believe the sun to be an *opaque* body, probably a habitable world; and that the light and heat we receive from it are owing to an atmosphere which it has, of elastic fluids of a phosphorescent nature, by the decomposition of which, light and heat are evolved. (Philosophical Transactions 1801, p. 265.) Aristotle conjectured that the sun was not a body of fire. *Pursuits of Literature, 2d edition, part iv. p. 96.*

"Hail to that orb, from whose rich fountain flow
Beams that illume and glad the world below!
Unseen by thee, had Nature mourn'd;
No smile her Æthiop cheek adorn'd;
Pale Night had spread her spectred reign,
And death-like horror rul'd the scene."

Dr. WALCOTT.

See an interesting paper on the nature and construction of the sun and fixed stars, in Philosophical Transactions for 1794.

When chemists require a very intense heat, it is procured by collecting the sun's rays by means of a double convex lens, or a concave mirror. This way of administering heat is particularly useful in operations on the gases.

If caloric passes with such velocity, how is it retained by those substances which receive it?

It is retained by its affinity for those bodies*, or rather their mutual affinity for each other.

Is the chemical affinity† of bodies for caloric in general very strong?

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* As caloric (like light) moves at the rate of 200,000 miles in a second, it never could be accumulated in any body, were it not retained by its *affinity* for that body. But for this retarding force, it would pass through the body with the rapidity of lightning, and leave not a trace behind it.

The rays of the sun seem to afford heat, only when they meet with an *opaque* substance, and not when they pass through a transparent one, as air or water; or when they are reflected by a white or polished one. The air is not heated immediately by the rays of the sun passing through it; but on their meeting with an opaque body, as the earth for instance, heat is elicited, and is thence gradually communicated to the surrounding atmosphere. Hence, the further we remove from the earth's surface the greater is the degree of cold.

The Swiss peasants, when they want to sow their seeds, spread black cloths on the surface of the snow, to absorb the sun's rays and facilitate its melting.

† Before a youth can have any accurate idea of chemical attraction, the nature of philosophical attraction should be explained to him, by means of a magnet and iron filings; by globules of water, of mercury, &c.

> "Hast thou not seen two pearls of dew
> The rose's velvet leaf adorn;
> How eager their attraction grew,
> As nearer to each other borne?"

GEO. HAY DRUMMOND.

It would be difficult to explain the nature of chemical affinity

No: it is one of the weakest of all known affinities*.

How does this appear?

From the facility with which heated bodies part with their caloric to all surrounding bodies†.

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to a youth without assisting his conception by experiments. Some of the plainest, and which may be performed without difficulty, may be seen in Additional Notes, No. 11.

* It is worthy of remark, that this was wisely and kindly ordered by the Creator; for, owing to this, organized bodies have no difficulty in separating a sufficient quantity of caloric from the substances around them, and of securing to themselves the quantity necessary for their wants. It is obvious how dreadful would have been the consequences, if caloric had had as strong an affinity for bodies, as some simple substances have for each other. A small deviation from the present order of things would probably occasion infinite mischief.

"By some curious experiments Mr. John Hunter discovered that the living principle in fish, in vegetables, and even in eggs and seeds, possesses a power of resisting congelation." (Darwin.) It appears that these must have some peculiar attraction for caloric.

† The facility with which caloric passes from one body to another may be owing to the repulsion which is known to exist among the particles of caloric. This repulsion gives it a tendency to fly off in every direction.

Count Rumford has asserted, that fluids are non-conductors of heat; but Mr. Murray of Edinburgh has demonstrated the contrary by experiment. See his papers in Nicholson's Journal, vol. i. 8vo. 165—241.

The motion of caloric through bodies is of two kinds: through some bodies it moves with the same rapidity as through free space. Through other bodies it moves with a remarkably slow motion. In the first case it is said to be *transmitted*

Is this universally the case?

Yes: it seems to be one of the laws of nature, that heated bodies should give out *part* of their free caloric to the neighbouring bodies at a lower temperature, till the whole become of an equal degree of temperature*.

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through the body, in the latter *conducted* through it. For particulars consult Dr. Thomson's paper on the motion of caloric, vol. i. 310.

* Some bodies give out their superabundant caloric much sooner than others. Iron is a quicker conductor of caloric than glass, and glass is a better conductor than wood. Hence the use of wooden handles to metallic tea-pots and other utensils.

I take a piece of iron in one hand, and a piece of wood in the other; the iron feels cold, the wood warmer, though the thermometer shows that their temperature is the same. How is this? The iron has a stronger affinity for caloric than wood, and conducts it from the hand much swifter than the wood, and hence gives me a more lively sense of cold.

Some of the earths are very slow conductors of heat. Sand is eminently so. "The red-hot balls, employed by the garrison of Gibraltar to destroy the Spanish floating batteries, were carried from the furnaces to the bastions in *wooden* barrows with only a layer of sand interposed; and this was found sufficient to prevent the balls, though in a high state of incandescence, from setting fire to the wood." Tilloch.

The necessity of one body being endowed with a greater power to conduct caloric than another, is apparent in many instances; but perhaps the nature of snow in this respect renders us a more important service than any other substance. Owing to the distance of this globe from the sun, and to the vast mountains of ice at the poles, the atmosphere over a large portion of the earth is at times reduced to so low a temperature, *Give me an instance of the operation of this law of nature.*

When the temperature of the atmosphere is reduced below 32°, water gives out its superabun-

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that, were it not for a wise provision of nature, all vegetable life must be destroyed. Caloric has always a tendency to equilibrium; therefore, if the temperature of the air be lowered, the earth cools in proportion: but, when the atmosphere is reduced to 32°, the water which it held in solution becomes frozen, and precipitates in the form of snow upon the earth, covering it as with a carpet, and thereby preventing the escape of that caloric which is necessary for the preservation of those families of vegetables that depend upon it for their support and maturity. Be the air ever so cold (and in the northernmost parts of the Russian empire it is sometimes 70 degrees below the freezing point) the ground, thus covered, is seldom reduced below 32°, but is maintained equably at that temperature for the purpose above mentioned. How multiplied are the means which Nature has adopted for the preservation of all her productions!

The constant tendency of caloric to the state of equilibrium is very clearly expressed by Mr. John Thomson of Edinburgh. "When a mercurial thermometer," says he, "is immersed in water, the caloric of the water makes an effort to diffuse itself through the mercury, and the caloric of the mercury makes an effort to diffuse itself through the water. If the tendencies to expand be equal in these two quantities of caloric, both quantities will remain at rest. But when the tendencies to expansion are unequal, the caloric is impelled from the substance where it had existed in the state of the greatest tension, into the substance where it had existed in the state of the least tension. When this happens, the degree of the dilatation or contraction of the mercury is said to indicate the *temperature* of the substance to which it is applied." Notes on Fourcroy, vol. i. page 178. For a further elucidation of this subject, consult dant caloric by degrees, till at length the cold atmosphere robs it of its caloric of fluidity also, and it becomes ice*.

If water be changed into ice by parting with its caloric, how comes it to pass that ice swims upon the surface of the water?

Because, by the change which it undergoes, it becomes specifically lighter than the subjacent water†.

Dr. Thomson's Chemistry, vol. i. page 335; and Philosophical Transactions for 1802, page 403.

[*] The quantity of heat given out in freezing, occasions the progress of congelation to be extremely slow. The constant emission of caloric from the freezing substances operates favourably; for thus the severity of the frost is mitigated, and its progress retarded. This accounts for its often feeling warmer after a great fall of snow. On the other hand, if the return of caloric to the frozen body of water were not equally slow, what sudden inundations would be occasioned, in those countries where large masses of ice are collected, at the first approach of summer! as has before been remarked. That the melting of ice produces cold, is seen in many operations. By melting ice with common salt, confectioners produce cold much greater than that of the original ice.

[†] Ice is lighter than water, owing to air-bubbles produced in the ice while freezing: but Monsieur de Mairan attributes the increase in the bulk of water in freezing to a different arrangement of its particles; ice being a crystallization composed of filaments, which are found to be uniformly joined at an angle of 60°, and by this disposition occupy a greater volume than if they were parallel. See Dr. Rees's Cyclopædia, article Ice; and Dr. Black's Lectures, vol. i.

That ice contains a large portion of air, may be seen by the following experiment. Drop small pieces of ice into a tall

Did you not say that all substances become more dense by the loss of caloric?

They usually do; but the freezing of water is a striking *exception*[*] to this general law of nature,

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glass full of hot water; as the ice melts, bubbles of air will be seen to rise from it, and burst at the surface of the water.

[*] We are acquainted with a few other exceptions. Saline solutions expand in cooling as crystallization takes place: and more perfect castings of iron may be had than of almost any other metal, in consequence of iron always enlarging as it cools, and filling the most minute parts of the mould into which it may be poured when in a fluid state; but we know of no fluid that has a *maximum* of density like water, and that expands whether heated above or cooled below that temperature.

In general, all bodies, whether solid or fluid, contract their dimensions and become of more specific gravity in cooling. This axiom has been long known and acknowledged; but *water* affords a remarkable and striking exception. Water as it cools below 42°.5, instead of contracting and becoming of greater specific gravity, actually becomes increased in bulk, and its specific gravity continues to lessen as it cools. Count Rumford noticed this fact some years ago in one of his early essays. His remarks, if I mistake not, are accompanied with some ingenious calculations, to which I refer the reader. Sir C. Blagden has, from actual observations, made a table of the specific gravity of water of different temperatures between 30 and 40 degrees.

40———1000.54 bulk
37———1000.55
36———1000.56
35———1000.58
34———1000.60
33———1000.63
32———1000.66
31———1000.70
30———1000.74

and is a memorable instance of the wisdom and provident care of the Almighty, when he established the laws of the universe.

Since these experiments, Mr. Dalton has discovered that the expansion of water is the same for any number of degrees above or below the maximum of density. Therefore the density of water at 32° and at 53° is precisely the same. The bulk of water at 5° is equal to the same bulk of water at 80°. Manchester Memoirs, vol. v. 374.

From these experiments, we see that water becomes of less specific gravity, whether it be heated *above* or cooled *below* 42°.5; a fact too astonishing ever to have been discovered or imagined a priori. The wisdom and goodness of the GREAT ARTIFICER of the world will manifest itself in this arrangement, if we consider what would have been the consequences had water been subject to the general law, and, like other fluids, become specifically heavier by the loss of its caloric. In winter, when the atmosphere became reduced to 32°, the water on the surface of our rivers would have sunk as it froze; another sheet of water would have froze immediately, and sunk also; the ultimate consequence of which would have been, that the beds of our rivers would have become repositories of immense masses of ice, which no subsequent summer could unbind; and the world would shortly have been converted into a frozen chaos. How admirable the wisdom, how skilful the contrivance, that, by subjecting water to a law contrary to what is observed by other fluids, the water as it freezes becomes specifically lighter, and, swimming upon the surface, performs an important service by preserving a vast body of caloric in the *subjacent* fluid from the effects of the surrounding cold, ready to receive its own accustomed quantity upon the first change of the atmosphere!

These reflections, perhaps, will not be thought to be misplaced, should they but afford

> " One ray of light in this terrene abode,
> To prove to man the goodness of his God."

CHAP. IV.

OF WATER.

What is water?

Water is a compound consisting of hydrogen and oxygen.

In how many states do we find water?

In four: solid or ice; liquid or water; vapour or steam; and in a state of composition with other bodies.

Which is the most simple state of water?

That of ice.

What is the essential difference between liquid water and ice?

Water contains a larger portion of caloric*.

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* Ice at 32° must absorb 140° of caloric before it can become fluid; or such a quantity as would raise a body of water of equal bulk with itself from 32° to 172°. This may be made very evident to a youth who has been taught the use of a thermometer, by the following directions:

"Take any quantity by weight of ice or snow at 32°, and mix it with an equal weight of water heated exactly to 172°. The snow instantly melts, and the temperature of the mixture is still only at *thirty-two* degrees. Here the water is cooled 140°, while the temperature of the snow is not increased at all; so that 140° of caloric have disappeared. They must have

How do you define vapour?

Vapour is water, combined with a still greater quantity of caloric*.

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combined with the snow; but they have only melted it, without increasing its temperature. Hence, it follows irresistibly that ice, when converted into water, absorbs and combines with 140° of caloric. Water then, after being cooled down to 32°, cannot freeze till it has parted with 140° of caloric; and ice, after being heated to 32° (which is the exact freezing point), cannot melt till it has absorbed 140° more of caloric. This is the cause of the extreme slowness of these operations. There can be no doubt, then, but water owes its fluidity to the caloric which it contains, and that its caloric of fluidity is 140°." Thomson's Chemistry, vol. i. 365.

The advantages which we derive from the slowness of these operations, and the inconveniences we should have suffered, had it been otherwise, are numerous and obvious. See notes page 104 and 117; and Additional Notes, No. 5.

* However long we boil a fluid, in an open vessel, we cannot make it in the smallest degree hotter than its boiling point. When arrived at this point, the vapour absorbs the heat, and carries it off as fast as it is generated. Yet by continued heat, united with additional compression, both the expansibility and temperature of steam may be greatly increased; and some constructors of steam-engines have lately availed themselves of this property, to augment the power and diminish the expense. See note page 60; also Additional Notes, No. 3 and 4.

Those who have an air pump may easily see that water requires a vast portion of caloric to convert it into steam; for, if a cup of *hot* water be put under the receiver, and the pump be set to work, the water will soon begin to boil furiously, and the receiver will be covered with vapour. If the receiver be now taken off, the water will be found barely lukewarm, owing to the vapour having carried off the greatest part of its heat.

What are the properties of vapour?

Vapour, owing to the large quantity of caloric which is combined with it, takes a gaseous form, acquires great expansive force*, and a capability

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Water, in being converted into vapour, combines with more than five times the quantity of caloric that is required to bring ice-cold water to a boiling heat, and occupies a space 800 times greater than it does when in the form of water.

Owing to the quantity of caloric that liquids require to convert them into vapour, all evaporation produces cold. It has been remarked before, that an animal might be frozen to death in the midst of summer, by repeatedly sprinkling ether upon him. Its evaporation would shortly carry off the whole of his vital heat. Water thrown on hot bodies acts in the same way; it becomes, in an instant, converted into vapour, and thus deprives these bodies of a great portion of the caloric they contain.

The most striking example, that I have seen, of the production of cold by rarefaction, is given by Dr. Wolfe in his account of the fountain of Hiero, at the mines of Chemnitz in Hungary. In this curious machine, of which he has given a plate, the air is compressed by a ponderous column of water, 260 feet high; it therefore happens, that whenever the stop cock is opened, this compressed air rushes out with great vehemence, becoming immediately much expanded. The consequence of this sudden rarefaction is, that the moisture the air contained is not only precipitated, but congealed; a part of which falls down in a shower of snow, and the other part forms icicles which adhere to the nozle of the cock. Philosophical Transactions, vol. lii.

* The expansive force of steam is found by experiment to be much greater than that of gunpowder.

Some volcanic eruptions and earthquakes, it is supposed, owe their terrible effects to this power of steam; the water of of supporting enormous weights*; whence it has become a useful and powerful agent for raising

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the sea finding its way to subterraneous fires. See an account of the dreadful effects of the earthquake at Catania, in the notes to Madame de Genlis's Tales of the Castle, vol. ii. 241; or in Sir Wm. Hamilton's splendid survey of the two Sicilies.

In boiling oil, the workmen are very careful to prevent any water coming near it; for a single drop coming among it would instantly, by the excessive heat of the oil, be converted into vapour, and would force part of the oil over the sides of the boiler.

It is to the expansive force of steam that the well-known motion in water called boiling, is to be ascribed. The vapour is first formed at the bottom of the vessel, and, passing through the water, causes that motion in it which we call ebullition.

* The invention of the steam-engine was a vast acquisition to the arts. There is reason to believe that, in time, steam may be applied to many useful purposes, of which at present we have no idea. In America vessels are already navigated by steam.

> "Soon shall thy arm, unconquer'd steam! afar
> Drag the slow barge, or drive the rapid car,
> Or on wide waving wings expanded bear
> The flying chariot through the fields of air."—DARWIN.

The steam-engine, approaching to the nature of a *perpetuum mobile*, or rather an animal, is incapable of lassitude; it procures for us coals; it works metals; moves machines; and is certainly the noblest drudge that was ever employed by the hand of art. Thus we "put a hook in the nose of the leviathan; play with him as with a child; and take him for a servant for ever:" thus we subdue nature, and derive aid from the elements of earthquakes. Analytical Review.

The steam-engine is brought to such perfection, that one bushel of coals will raise 6,000 hogsheads of water ten feet water from deep pits, and for other important purposes*.

In what proportions are oxygen and hydrogen† in water?

Water is composed of 85 parts by weight of

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high, and do the work of ten horses. Where there is no waste of steam, this work may be performed continually with the consumption of only one bushel of coals per hour. Some of the engine chambers in London are now fitted up with great taste, and are kept with the utmost neatness; in these one may spend hours without being annoyed by the escape of the most minute portion of steam.

Dr. Black calls the steam-engine, the master-piece of human skill, and the most valuable present that was ever made by philosophy to the arts.

[*] Steam is now employed in a vast variety of ways in the different manufactories of this kingdom. It is used with great œconomy of fuel in the dye-house of Mr. Desange, in Wheeler-street, Spital-fields. Messrs. Gott and Co., of Leeds, boil 30 large coppers by the steam of one boiler. It is employed elsewhere in drying malt, linen, coffee, paper, &c., and might be used with peculiar advantage in drying gunpowder. Dr. Black remarks, that steam is the most faithful carrier of heat that can be conceived, as it will deposit it only on such bodies as are colder than 212°.

Water heated to 220 degrees or upwards is found to be very effectual in bleaching linen goods. This method is coming into practice in the North of England. I am told that the necessary pressure is given by means of large chambers constructed of massy stone; and that in these chambers the linen is submitted to the action of the condensed steam.

[†] Both these terms are derived from the Greek language; the former signifies to *generate acids*, the latter to *generate water*.

oxygen, and 15 of hydrogen*, in every 100 parts of the fluid.

How is it known that water is a compound substance†?

Several methods have been contrived by chemists whereby water may be decomposed, and

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* Hydrogen appears capable of uniting with oxygen only in *one* proportion, and water is the result of the composition.

Of all the known substances, there is not any of which an equal weight can combine with so large a portion of oxygen, covering at the same time its characteristic properties, as hydrogen; but losing also all those which characterize itself:—it requires only 15 of hydrogen to saturate nearly 85 parts of oxygen to this point, that is, to form water.

As water does not permit any property of oxygen or hydrogen to be perceived, it may be concluded that these two substances are combined at the point at which the reciprocal affinity exercises the greatest effect; and that they are in a state which may be compared with that of a neutral salt, in which the acid and alkaline properties have equally become latent. Berthollet.

† This was discovered by Mr. Cavendish, in the year 1781. Dr. Priestley had previously combined the two gases by combustion; but Mr. Cavendish was the first who drew the proper conclusion from the Doctor's experiment. The benefit which the world has derived from the labours and communications of such men is incalculable. "Nature," says an elegant French writer, "in order to unite mankind by a reciprocal communication of knowledge, has given to each individual his particular ignorance; and has placed science as a common stock to render us necessary and interesting to each other."

From a passage in Virgil's Georgics, lib. ii. 325, one would be tempted to believe that the ancient chemists of Egypt had discovered the composition of water. See Darwin's Botanic Garden, book i. 136.

the exact proportion of its constituent parts ascertained[*].

Do you know any of the methods of decomposing water?

Yes, there are several: it may be done by passing it through a tube over red-hot charcoal[†], by passing repeated electrical shocks through it, or by means of the galvanic apparatus[‡].

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[*] A history of the discovery of the composition and decomposition of water, with the curious facts relating thereto, may be seen detailed in a familiar and pleasing manner, by Mr. John Thomson, in his valuable Notes on Fourcroy, vol. i. 237, &c. The operation of electricity or galvanism, in uniting the two gases to form water, is explained by Mr. Murray, with great perspicuity in the notes to his System of Chemistry, vol. i. p. 25.

[†] "Water cannot be decomposed without a combustible body," or the agency of electricity or galvanism, "as the hydrogen requires a very large dose of caloric to put it in a gaseous state. This appears from the lightness of hydrogen gas compared with water. A cubic foot of water weighs 62½ pounds, whereas a cubic foot of hydrogen gas weighs only 61 grains. See Additional Notes, No. 13.

[‡] When two wires from the opposite extremities of a galvanic battery are placed in a tube containing water, so that they are distant from each other ¼ or ½ an inch, a stream of gas issues from each wire—from the positive wire oxygen, from the negative, hydrogen gas; and these are in the proportions which when exploded, either by galvanism or electricity, reform water. See more on this subject in Murray's Chemistry, vol. ii. p. 172.

Some French aëronauts decomposed water by the galvanic

Does nature decompose water in any of her operations?

Certainly, by many: particularly by means of every living vegetable; all vegetables having the power of decomposing water, by a secret operation peculiar to themselves*. Fish in general, and all cold-blooded amphibious animals, we have reason to think, are endowed also with the same faculty†.

For what purpose are vegetables endowed with this power of decomposing water?

They combine part of its hydrogen, as well as of its oxygen, with the carbon of the atmosphere and of the soil, to form the vegetable

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pile at an elevation of near three thousand metres from the earth. Phil. Mag. vol. xix. 374.

The decomposition of water by electricity or galvanism, which produces an intense heat, seems to prove that there is a degree of temperature at which water cannot exist, but in which it is reduced to its two elements. Berthollet.

Water is often partially decomposed by being kept for a long time in casks, especially on long voyages. The wood combines with its elements, forming, amongst other impurities, carburetted hydrogen. Hence the disagreeable taste and smell which are observable in such water. If the cask be charred on the inside, it will not operate in this way.

* See page 84, and Additional Notes, No. 18.

† Among other cases, we read of a fish that was kept three years in a vessel and fed only with water, and that at last it became too large to live any longer in the vessel. Whence this increase of animal substance, if we deny it the power of decomposing water? Rondelet. de Piscibus, lib. i. cap. 12.

compounds oil[*], wax[†], gum, resin, sugar, &c.; while the superfluous oxygen[‡] is abundantly evolved by the leaves;

> "Killing infectious damps, and the spent air
> Storing afresh with elemental life."

Can you recapitulate what has hitherto been detailed of the nature of oxygen[§]?

Yes: oxygen is the basis of vital air, as well as

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[*] It should always be recollected that the oil found in vegetables is produced by this process of vegetation. The oils, bitumens, &c. in minerals, must all have had a vegetable origin.

In the duchy of Modena, mineral oil is separated from bituminous coals by a natural subterranean distillation. The inhabitants of the district, by piercing the sides of a particular rock, at different distances from its summit, obtain oil of different kinds, thickening, and growing deeper-coloured, as the channels through which they flow approach to the surface of the earth. Bishop Watson.

[†] In Louisiana and Pennsylvania, the *myrica* is cultivated solely for the *wax* which it produces. In China, vegetable wax is extracted from plants by maceration in boiling water, and employed in the manufacture of candles.

Bees' wax is doubtless a vegetable product. The bees extract it unaltered from the leaves of trees, and other vegetables. They seem, however, to mix it with some of the pollen of flowers. The comb which these insects form with the wax, is a collection of hexagonal cells closely fitted to each other. It may be remarked that no other geometrical figure could have been chosen for them, that would have been equally capacious, without any loss of room; so that the operation of infinite wisdom is apparent even in the impression of that instinct whereby these little animals are directed to fabricate their cells in that particular form and in no other.

[‡] See note page 84.

[§] Nature, in œconomizing the primary materials of the one of the constituent parts of water; it is the chief support of life and heat; and performs an important part in most of the changes which take place in the mineral, vegetable, and animal kingdoms*.

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universe, has constituted *oxygen* the basis both of the atmosphere which surrounds the earth, and of the water which forms its seas and oceans.

> " For mark how oxygen with azote gas
> Plays round the globe in one aërial mass,
> Or, fused with hydrogen in ceaseless flow,
> Forms the wide waves which foam and roll below."
>
> DARWIN.

We see in this and other instances, by what simple means the most beneficial effects have been produced.

* Some idea may be formed of the importance of oxygen, by attending to the analysis which Lavoisier made of the materials necessary for fermenting 100 pounds of sugar.

	lbs.				*lbs.*	*oz.*
Water	400	Oxygen of the water .			340	
Sugar	100	Ditto of the sugar . .			64	
Yeast	10	Ditto of the yeast . .			7	12¾
	510				411	12¾
		Hydrogen of the water	60	0		
		Ditto of the sugar	8	0		
		Ditto of the yeast	1	6		
					69	6
		Carbon of the sugar	28	0		
		Ditto of the yeast	0	12½		
					28	12½
		Nitrogen in the yeast			0	¾
					510	0

What is hydrogen, the other constituent part of water?

Hydrogen is the base of the gas which was formerly called inflammable air, and is, when in the aëriform state, the lightest of all ponderable things*.

Has any method been discovered of composing *water by a mixture of oxygen and hydrogen?*

Yes: there are several ways of doing this†; so that the composition of water is now ascertained beyond all doubt‡.

It appears from the above analysis that more than four-fifths of the whole is oxygen. See a further account of oxygen in chap. 10.

[*] Hydrogen gas, from its great levity, has generally been used to fill air-balloons. The following is the best way of procuring it: Put a quantity of filings of zinc into a vessel which has a glass tube adapted to it; then pour upon them sulphuric acid diluted with 6 or 8 times its quantity of water, an effervescence will immediately take place; the water will be decomposed, the oxygen of it will become united to the metal, and the hydrogen gas will be disengaged, and may be conveyed by the glass tube into any proper receiver. This gas can be procured pure only from water, which in all cases must suffer a decomposition. See a further account of hydrogen and its compounds in chap. 11.

[†] An ingenious and simple apparatus for the re-composition of water has been invented by Mr. Cuthbertson. A drawing and description of it may be seen in Nicholson's Journal, i. 235, 4to.

[‡] The decomposition of water and its subsequent re-formation may be shown by the following easy experiment: Mix gradually four ounces of water with one ounce of sulphuric

Do you know any of the methods which have been employed to form water by a mixture of its constituent parts?

Yes: if a mixture of oxygen and hydrogen gases, in proper proportion, be fired, the inflammation will unite the bases of the two gases, without separating the whole of their caloric, and water will be the product§.

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acid in a large phial, to which add a few iron filings. The temperature of the mixture will be so much raised by the union of the water with the acid, as to enable the iron to decompose a part of the water. If a hole be neatly made through a cork which fits the mouth of the phial, and a piece of tobacco-pipe with a very small orifice be fitted into it, and the whole cemented into the phial with a mixture of resin and bees' wax, the hydrogen gas as it is separated from the water will pass in a continued stream through the pipe, and may be set on fire by the flame of a candle brought in contact with it. The gas will continue to burn with a blue lambent flame, as long as the decomposition goes on. This shows that the gas is really hydrogen, and that it arises from the decomposition of the water.

That water may be re-formed by the combustion of this gas, may be shown by holding a glass bell over the flame of the gas: as the hydrogen burns it unites with the oxygen of the atmosphere, and the union of the two gases produces water, which will soon be seen to deposit itself like dew on the inside of the glass. It is advisable to fold a cloth round the bottle to prevent any injury from the fragments of glass, in case of an explosion, which sometimes will happen during this experiment, if atmospheric air be left in the phial; or let the gas burn for a moment, before the cork and pipe are fixed into the neck of the bottle.

§ In Lavoisier's Elements of Chemistry, a copper-plate print

Is there any reason to suppose that water is thus formed in any of the great operations of nature?

Yes: it is probable that the torrents of rain which generally accompany thunder storms, may arise from a sudden combustion* of hydrogen and oxygen gases†.

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of an excellent apparatus for composing water may be seen, with a full and satisfactory description of the method of making use of it. See Additional Notes, No. 13.

M. Biot has succeeded in forming water from hydrogen and oxygen, by *compression* only, independently of the electric spark. The compression, by bringing the particles of gas into intimate union, makes them throw out heat sufficient to set them on fire; and the product of the combustion is water.

It here occurs, that the affinity of hydrogen for oxygen may be exemplified by the large portion of oxygen which all combustible bodies containing much hydrogen require in combustion; affording water as the product. Thus, one pound of highly rectified spirits of wine on being burnt will produce more than its own weight of water. See Additional Notes, No. 16.

* This combustion is probably occasioned by lightning.

† The aurora borealis is probably owing to the existence of a stratum of hydrogen gas in the higher regions of the atmosphere, which being lighter than atmospheric air would keep that situation till ignited by electricity. The vulgar have had strange conceits about this curious phænomenon of nature.

> "Not so the man of philosophic eye
> And inspect sage; the waving brightness he
> Curious surveys, inquisitive to know
> The causes and materials (yet unfix'd)
> Of this appearance beautiful and new." THOMSON.

How is the atmosphere furnished with this hydrogen gas?

Hydrogen is constantly emanating from, and is the consequence of, every species of vegetable and animal decay or putrefaction; and it is also evolved from various mines, volcanoes, and other natural sources[‡].

What is the specific gravity of water?

A wine-pint measure of water weighs one pound[§]; a cubic foot of water weighs about 1000 ounces, or 62½ lbs. avoirdupois. It is 816 times heavier than atmospheric air[‖].

What change does water undergo in order to be converted into ice?

The atmosphere, when its temperature is suf-

[‡] Hydrogen gas is only one thirteenth of the weight of atmospheric air, and occupies a space fifteen hundred times greater than it possessed in its aqueous combination.

The ignis fatuus, or will-o-wisp, originates from decayed vegetables, and the decomposition of pyritic coals; it consists generally of hydrogen combined with carbon; and, perhaps, occasionally with phosphorus or sulphur.

> "Thus heat evolved from some fermenting mass
> Expands the kindling atoms into gas."

Dr. Shaw, in his Travels in Palestine, has given a curious account of an ignis fatuus which he observed there.

[§] It is necessary for the student to bear in mind the specific gravity of water, because this is always taken for unity in the measure of the specific gravity of every other substance.

[‖] This estimate is agreeably to the last experiments made by Sir Geo. Shuckburgh, when the barometer is at 30 inches, and the thermometer between 50° and 60°.

ficiently low, deprives the water of a certain portion of its caloric—crystallization then ensues and the water solidifies and becomes ice*.

What do you mean by crystallization?

By crystallization is understood the concretion of certain substances into regular forms, occasioned by the loss of a portion of their caloric.

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* Water in freezing crystallizes in filaments, which are uniformly joined at an angle of 60 degrees.

It has been said that water may be purified from the putridity which may be contained in it by *freezing*; and that in such water the portion which freezes is pure, while that which remains fluid is contaminated with noxious matter. Dr. Lamb on Constitutional Diseases.

It is owing to the *expansion* of water in freezing, that rocks and trees are often split during intense frosts. According to the calculations of the Florentine academicians, a spherule of water, only one inch in diameter, expands in freezing with a force superior to the resistance of 13½ tons weight. Major Williams also attempted to prevent this expansion; but during the operation the iron plug which stopped the orifice of the bomb-shell containing the freezing water, and which was more than two pounds weight, was projected several hundred feet with great velocity; and in another experiment the shell burst. The imbecility of man never appears so conspicuous as when he attempts to counteract the operation of laws which were designed by infinite beneficence for his preservation and comfort. The law in question is eminently important, and nature has made it unalterable.

This property of water is taken advantage of in splitting slate. At Colly Western the slate is dug from the quarries in large blocks; these are placed in an opposite direction to what they had in the quarry, and the rain is allowed to fall upon them: it penetrates their fissures, and the first sharp frost freezes the

To what substances is the term usually applied?

The term is generally applied to compound bodies of the saline kind, and to their separation, in regular and peculiar figures, from the water in which they were dissolved[†].

You have said that ice is the most simple state of water; do you then imagine that water is naturally solid?

Yes: for underneath the poles it is eternally

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water, which, expanding with its usual force, splits the slate into thin layers.

It was necessary for the preservation of the world, that water should in this instance be subjected to a law different from that of other substances which change from fluid to solid. For an account of this important deviation from a general law of nature, see note chap. iii. page 117.

It may be remarked, that though fresh water freezes when reduced to the temperature of 32°, sea water does not freeze till cooled down to 28.5°. Was not this designed by nature to keep the ocean open at all seasons, that there might be no impediment to that general intercourse among nations which tends so much to promote their civilization and refinement?

"For this the ship, in floating balance held,
By earth attracted and by seas repell'd,
Directs her devious track, through climes unknown,
That leads to every shore and every zone." FALCONER.

[†] Crystallization is a kind of precipitation, in which the salt as it separates from the solvent assumes peculiar determinate forms. Mr. Smithson has shown that crystallization cannot take place while solution subsists, and that the only requisite for this operation is a freedom of motion in the masses which tend to unite. Phil. Trans. for 1803, page 27.

solid; there it is similar to the hardest rocks*,

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* There happen cracks at certain times in the ice mountain of Switzerland, which have shown the great thickness of the ice; some of these cracks have measured 300 or 400 ells deep. Near Hudson's Bay there are islands of ice which are immersed above 100 fathoms beneath the surface of the sea, and which measure three or four miles in circumference. Phil. Trans.

"There can be no doubt but that the quantity of ice at the north pole is the principal source of the coldness of our winters, and that it is brought hither by the regions of air blowing from the north."

"Where, for relentless months, continual night
Holds o'er the glittering waste her starry reign."

The ice at each pole of the earth forms an immense cupola, the arch of which extends some thousand miles over the continents; the thickness of which, beyond the 60th degree of latitude, is several hundred feet. Navigators have assigned to detached masses, which are met with floating at sea, an elevation of from 1500 to 1800 feet. See Ellis's Voyage to Hudson's Bay.

There can be no doubt but that the thickness of these cupolas of ice is much greater nearer the poles; for astronomy sometimes presents in the heavens so vast an image of them, that the rotundity of the earth seems to be considerably affected thereby. Captain Cook could never approach nearer the south pole, where there is no land, than the 70th degree of latitude; that is, no nearer than 1500 miles; though he had coasted round it for a whole summer; and it was only under favour of a bay that he was permitted to advance even so far. St. Pierre's Studies, vol. i. 129—132.

From a late memoir by Mons. Perron, there is reason to believe that these mountains of ice at the poles, which have hitherto impeded the progress of European navigators, have and may be formed by the chisel of the statuary, like stone†.

Is this great solidity of ice at the poles, owing to its being frozen in such large masses?

The great solidity of ice at the poles is occa-

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been detached from the depths of the sea to float at the surface. All the results of observations made by him and other navigators, concur in proving that the temperature of the sea decreases according to the depth; and that the deepest gulfs of the sea are continually covered with ice, even under the equator. A translation of this interesting memoir may be found in the 21st volume of the Philosophical Magazine.

† "It is related that at the whimsical marriage of Prince Gallitzin, in 1739, the Russians applied ice to the same purposes as stone. A house consisting of two apartments was built with large blocks of ice; the furniture of the rooms, even the nuptial bed, was made with ice; and the icy cannon, which were fired in honour of the day, performed their office more than once without bursting." Bishop Watson.—See Additional Notes, No. 17 and 5[illegible]5

In the most northern part of the Russian territory, the cold is sometimes sufficient to freeze mercury, or 72 degrees below the freezing point of water. It is so intense in some seasons, that the poor inhabitants cannot venture out of their miserable huts but at the hazard of their lives. See Additional Notes, No. 17.

"There, through the prison of unbounded wilds,
Barr'd by the hand of Nature from escape,
Wide roams the Russian exile. Nought around
Strikes his sad eye, but deserts lost in snow,
And heavy-loaded groves, and solid floods,
That stretch athwart the solitary vast
Their icy horrors to the frozen main." THOMSON.

sioned by the very low temperature of the circumambient air*; and in very cold countries ice may be ground so fine as to be blown away by the wind, and will still be ice.

Is ice the only instance of water existing in a state of solidity?

No: water becomes still more solid in mortar and cements, (see the note on the properties of lime, chap. v. page 163,) having parted with more of its caloric in that combination than it does in the act of freezing†.

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* We need not look for any cause for the conversion of water into ice, but the loss of its caloric; for in the Grotto of Besançon water is frozen during the heats of summer. In this singular place the variation of the thermometer between winter and summer is very inconsiderable.

Though water be converted to ice by the loss of caloric, there is reason to suppose that ice, notwithstanding, contains more caloric than was disengaged between the state of vapour and that of congelation. See Berthollet's Statics, vol. i. 134.

I have been informed by some intelligent workers in iron and steel, that they have great difficulty in making tools hard enough to cut ice in extremely *cold* winters; and that in such seasons the workmen are under the necessity of having their instruments very frequently repaired.

† Though water takes a solid form in its various combinations, such as with lime, saline crystals, &c.; we know of no method of compressing it when in a fluid state. The Florentine academicians filled a globe of gold perfectly full of water, and submitted it to a very powerful press; but could not perceive that they were able to make it occupy less space than it did at first. They gave it such a degree of pressure, that at length the water exuded through the pores of the metal.

What other instances are there of water taking a solid form?

Water is combined in a state of solidity in marble, in crystals, in spars, in gems, and in all alkaline and earthy salts; to all of which substances it imparts hardness, and to most of them transparency[‡].

What are the general and more obvious advantages which we derive from water?

Water is a necessary beverage for man and

[‡] Most stones and salts lose their solidity and transparency by being deprived even of a part only of the water which they contained, and generally become pulverulent. It is by a combination with water that some of the gases are rendered liquid substances, and that some liquids acquire the property of becoming fixed. This may be satisfactorily shown by boiling a few copper filings in concentrated sulphuric acid, with a small portion of nitric acid, till the copper is dissolved; then adding water, and leaving the mixture to cool gradually; when beautiful crystals of blue vitriol will be found, as hard as some minerals. It is the water which gives them their solidity;

"That chief ingredient in Heaven's various works,
Whose flexile genius sparkles in the gem,
Grows firm in oak, and fugitive in wine." ARMSTRONG.

If water be thrown on quick-lime, it will be retained by it with such force that nothing less than an intense *red* heat will separate it. In its combination with lime it becomes much more solid than when in the state of ice; which may be proved by direct experiment. Calcined plaster of Paris, in a pulverulent state, becomes quickly solid by mixing it with water. Saussure has proved that alumine, when mixed with water, retains a tenth of its weight of that fluid at a heat which will melt iron.

other animals; is perpetually used as a solvent[*] for a great variety of solid bodies[†]; acts an important part in conveying nourishment to the vegetable world[‡], and giving salubrity to the atmospherical regions[§]; and lastly, by its accumulation in the ocean[‖], affords a ready commu-

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[*] It should be remembered, that all bodies which are soluble in water, form, during their solution, a chemical combination with the water, and cannot be separated therefrom by any mechanical means.

[†] Water is not only employed as a solvent for many solid substances, but has important uses in a variety of compounds. Besides imparting solidity to the classes of salts, it gives energy to the action of many of the acids, and is even necessary in their formation. Muriatic acid and nitrous acid gases are condensed so as to form liquid acids, merely by their union with water.

[‡] For an account of several modern experiments on the growth of vegetables in water, see the Additional Notes at the end of this volume.

[§] See note, chap. ii. page 84.

[‖] Some late experiments of Mr. Harrop's, related in the fifth volume of the Philosophical Journal, render it probable that the ocean and other large bodies of water may have been designed by nature as reservoirs for supplying an increased population with the oxygen necessary for its consumption, and for producing a regular renovation of the atmosphere. The immense quantities of marine productions found at very great heights above the present level of the sea, seem to indicate that there has been a prodigious recession of the ocean. While water was conceived to be a simple and indestructible substance, innumerable conjectures were afloat as to the channels which had been found for such an immense body of water. The new nication with distant countries;—the whole of which evidently teaches how provident the great AUTHOR of nature has been in his attentions to the comforts and conveniences, as well as to the wants of his numerous creatures.

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chemical doctrines have afforded us a clue by which to unravel this mystery, and fresh motives for admiring the exquisite contrivance of the great Author of all things.

——————— "That mighty hand
That, ever busy, wheels the silent spheres,
Works in the secret deep, shoots, *steaming*, thence
The fair profusion that o'erspreads the spring." THOMSON.

See this subject further investigated in the Additional Notes, No. 18.

I cannot resist making an extract from Mrs. Charlotte Smith's Observations on the Ocean:

"There are people," she says, "who think nothing but the human character deserves their study, and pass over the great works of God as unworthy the trouble of contemplating. But I wonder any being who affects *taste* would venture to assert that this immense body of water presents only sameness and monotony. To me it seems, that even the colours and sounds are little less varied than those we see or hear in the midst of the most luxuriant landscape."

"Ah! wherefore do the incurious say,
That this stupendous OCEAN wide
No change presents from day to day,
Save only the alternate tide?
Show them, its bounteous breast bestows
On myriads life; and bid them see
In every wave that circling flows,
Beauty, and use, and harmony.
Works of the Power Supreme who poured the flood
Round the green peopled earth, and called it good."

CHAP. V.

OF EARTHS.

What are the principal characters of a simple earth?

The earths in general are incombustible and unalterable in the fire; unsusceptible of decomposition*; insoluble in water, or nearly so, when combined with carbonic acid†; and of a specific gravity never exceeding five times that of water.

How many earths are there?

There are nine distinct earths known at present, viz. silex, alumine, zircone, glucine, yttria, barytes, strontian, lime, and magnesia‡.

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* Baron Born is of opinion that all the earths are metallic oxides. Fourcroy thinks that we are on the point of obtaining the decomposition of these bodies.

† Bergman classes all substances, except metals, with the earths, which require more than one thousand parts of water for their solution. We have, however, another test to distinguish them, when held in solution by acids, viz. the prussian alkali. Prussiate of potass, and indeed prussiates in general, have the property of precipitating all metallic oxides from their solutions; yet, excepting yttria, it has no effect on any of the earths.

‡ To a cursory observer the earths appear to be infinitely

Why are some of these earths called alkaline earths?

Barytes, strontian, and lime § are called alkaline because they agree with alkalies in taste, causticity, solubility in water, and in their effect on vegetable colours ||. Magnesia agrees with the alkalies in the latter property only.

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diversified; so much so, that he would probably think the different kinds are innumerable. However, notwithstanding the varied appearance of the earth under our feet, of that of the furrows of the field, and of the mountainous parts of the world, whose diversified strata present to our view substances of every texture and of every shade, the whole is composed of only nine primitive earths; and as three of these occur but seldom, the *variety* which is produced by the other *six* becomes the more remarkable. This may fairly be adduced as one instance of the infinite skill of the Deity, as it "bespeaks an artist master of his work, acquainted with his materials."

To give a still greater variety to the works of Nature, these earths are endowed with an affinity for acids and metallic oxides, whence arise the spars, gems, and precious stones of every colour and every species.

> "The unfruitful rock itself, impregn'd by thee,
> In dark retirement forms the lucid stone."

§ Barytes, strontian, lime, and magnesia, are found in nature always combined with acids. None of the combinations are very hard, as either of them may be scratched with a knife. The acids, which are found united by nature with these alkaline earths, are generally the carbonic, the sulphuric, the fluoric, the boracic, and the phosphoric.

|| Barytes, strontian, and lime, differ from the alkalies, in their infusibility by fire, in forming insoluble compounds with carbonic acid, and in being insoluble in alcohol. As these are the common properties of the earths, we have

What is the nature of silex; and what are its chief properties?*

Silex†, or pure flint, is insoluble in water‡,

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sufficient reason to reject the proposal of some of the French chemists, who are desirous of transferring these substances from the earths to the class of alkalies.

* In the first edition (p. 151), I announced the original and very singular opinion of *Mr. Hume*, of Long-Acre; namely, that *silex* is the *basis* of *oxygen gas*. In subsequent conversations with that gentleman, I have, I confess, been much surprised by the variety of natural and chemical facts, which he adduces in confirmation of his hypothesis; but, rather than present my readers with a mutilated detail of his arguments, and the nature of my plan admitting of no other, I shall leave all further notice of this important subject to himself, especially as it is, I believe, his intention to publish his ideas through some more appropriate channel.

† Should *pure* silex be wanted for chemical experiment, it may be procured by fusing common flint stones with three or four times their weight of potash, dissolving the product in water, and then taking up the alkali by the addition of an acid, which will precipitate the silex, which is to be well washed for use. The siliceous stones should be previously heated red in a crucible, and plunged in that state into cold water. This will render them brittle, so that they may easily be reduced to powder before they are mixed with the potash.

‡ We cannot by any means dissolve silex in water;—Nature, however, by some wonderful and unknown process, contrives to dissolve it, even copiously, so as to form stalactites and other incrustations. In Iceland there is a boiling fountain which spouts water 90 feet in the air, and deposits in falling so great a quantity of siliceous earth, that it forms around its base a sort of solid cup, which surmounts and envelops it. See note p. 6[illegible].1 This earth has also been found in solution in the Bath waters; and in some other spring water.

and in every acid except the fluoric; it endures the strongest heat without alteration §; but, when mixed with soda or potass, becomes fusible in a strong fire into glass. Its specific gravity is 2.65.

In what state is silex found native?

Silex, or siliceous earth, is found in quartz, in rock crystal, gravel, sand, and most of the precious stones ‖. It is also the chief ingredient of

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§ According to Saussure, quartz or silex may be fused by a heat equal to 4043° of Wedgwood; but this is a temperature so far above any heat that can be procured by common means, that I have not thought it necessary to alter the text. Mr. Hare also fused it by means of a stream of oxygen and hydrogen gases.

Sand sets into a less bulk when wet, and does not afterwards contract by heat. This property may be taken advantage of in constructing furnaces, &c.

‖ Mr. Kirwan, in his Geological Essays, relates, that about the year 1760 the emperor of Germany, being desirous to know the length of time necessary to complete a petrifaction, obtained leave from the Sultan to take up and examine one of the timbers that supported Trajan's bridge over the Danube, some miles below Belgrade. The outer part of this timber to the depth of half an inch was found to be converted to an *agate;* the inner parts were slightly petrified; and the central were still wood. The agate is a precious stone composed of silex and alumine, but chiefly silex.

Agate is brought to us from Germany in blocks. It is cut by means of diamond powder into leaves, for making caps for the pivots of mariners' needles to run in, and other purposes. Might it not be used advantageously for the balances of watches, those stones which seem to constitute the most bulky material of the solid parts of our globe*.

What are the chief uses of silex?

Silex is the most durable article in the state of gravel for the formation of roads; is a necessary

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instead of iron, which is liable to vary by magnetic influence and other causes?

* "A granite mountain, about 30 miles from the Cape of Good Hope, called the PEARL DIAMOND, rises out of the ground to the height of 400 feet, being half a mile in circumference; and formed of a single block of granite."—*Parkinson's Organic Remains.*

Silex also constitutes two thirds of the asbestus, so valued by the ancients for wrapping up the bodies of the dead before they were committed to the funeral pile. They discovered methods of drawing the fibres of the mineral into thread, and afterwards weaving it into cloth. In consequence of its incombustibility, it preserved the ashes of the body from mixing with those of the wood, upon which it was laid to be burnt. The practice was, however, probably confined to the families of the opulent. So late as the year 1702 a funeral urn was discovered at Rome, in which were a scull and other remains of a human body wrapped in a cloth of amianthus or flexible asbestus. The whole was deposited in the Vatican library.

This mineral might be manufactured into paper; and, for documents of great importance, it might perhaps be worth while to be at the expense of preparing this incombustible paper, and of writing upon it with indelible ink. The methods of making it into paper or cloth, and of preparing proper ink for writing upon it, may be seen in Dr. Rees's Cyclopædia. The mineral is found in Corsica; in the isle of Elba; in Sweden; and in Cornwall and the isle of Anglesea, in England.

The Chinese form furnaces with this mineral. They grind it, mix it up with some kind of mucilage, and introduce it into ingredient in earthen-ware, porcelain, and cements; is the basis of glass[†], and of all vitreous substances[‡]; and is an indispensable article in many of our chemical furnaces and utensils.

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moulds, the form and polish of which it assumes. These furnaces are very portable, and indestructible by fire. What kind of mucilage they employ is not known; but it is said that the mucilage of gum *adraganth* answers this purpose completely.

[†] The manufacture of glass was known very early; but glass perfectly transparent was reckoned so valuable, that Nero is said to have given 50,000*l.* for two glass cups with handles. When the excavations were made in the ancient city of Pompeii, which was buried by an eruption of Vesuvius A. D. 79, the windows of some of the houses were found glazed with a thick kind of glass, not transparent. In others isinglass was substituted, split into thin plates. Miss Starke's Letters from Italy.

The best book on glass-making, which I have seen, is an octavo volume, by H. Blancourt, with plates, 1699. But a scientific work, lately published in Paris by Loyzel, entitled "Essai sur l'Art de la Verrerie," is, I believe, the best modern work on this subject. It gives a detailed account of the different processes in this manufacture, and treats of each chemically.

The manufacturing of *pastes*, or artificial gems, is a branch of the art of glass-making. The basis of these is a very hard and pure silex, obtained by melting pounded quartz with an alkali, with the addition of borax, nitre, and oxide of lead, different metallic oxides being added to imitate the colour of the different gems.—*Murray.*

[‡] I would recommend to the perusal of the young reader, Fourcroy's account of the various uses of silex, in vol. ii. of his System of Chemistry, page 190. It is beautifully written, and cannot fail to interest and instruct the pupil.

What is the use of silex in glass-making?

Silex is the chief ingredient in glass. It is rendered fusible by a due mixture of alkali, which acts as a flux to the silex, and renders the whole transparent*.

Are these the only articles necessary to form glass?

In Holland, and some other parts of Europe, glass is manufactured with alkali and sand only; but in England, flint-glass is made by a mixture of red lead† with those substances; which gives

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* Glass cannot be made without great heat, as the alkali retains the last portions of carbonic acid and water with singular obstinacy, and it is only at a very high temperature that it prefers the silex; for it is one of the laws of nature, (to which there are few exceptions,) that, in order that two bodies may become *chemically* united, one of them must be in a state of fluidity.

† Metallic oxides have the property of making glass more fusible. The oxide of lead is serviceable in this way when mixed with glass. Plate and crown glass contain no lead, but the former has generally lime combined with it.

The common bottle-glass is made with a large portion of the ashes of vegetables, or soap-boilers' waste ashes, instead of pure alkali. The portion of iron, which is generally found in vegetable substances, gives it the green colour.

For the best flint-glass, rather more alkali is used than is necessary to flux the sand; and, when the whole is in fusion, the fire is continued so as to volatilize the superabundant quantity. If an extra quantity of alkali be left in the glass, it will attract water from the atmosphere, and in a short time assume a fluid the glass great weight, and makes it more useful for all common purposes.

What are the chief properties of alumine?

Alumine, or pure clay, is soft to the touch; adhesive to the tongue; emits a peculiar odour when moistened; forms a paste with water; will unite with most acids[‡]; and acquires great hardness, and contracts in the fire[§]. Its specific gravity is 2.

In what state is alumine found native?

This earth acquired its name from its being the basis of alum[||]; it has also been called *argil,* as it is the principal part of all clays[¶]; it is found

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state. This matter was by the old chemists called the *liquor of flint.*

Professor Seigling, having left a bottle of *liquor silicum* undisturbed eight years, found transparent *rock crystal* formed in it, hard enough to give fire with steel. See an account of a similar result in Nicholson's Journal, vol. i. 217.

[‡] Alumine is soluble in every acid, and in solutions of the caustic fixed alkalies.

[§] Alumine is completely fusible *per se* into a very hard vitreous kind of substance, hard enough to scratch glass; but sufficient heat cannot be procured to effect its fusion without oxygen gas. Saussure found that it required 18.900° of Wedgwood to fuse it; but when mixed with certain proportions of silex and lime, it fuses readily.

[||] Pure alumine may be procured by decomposing common alum with carbonate of ammonia. It has not been found native in a state of purity any where, except at Halle in Germany.

[¶] Common clay is a mixture of alumine and silex. It frein a state of crystallization in the sapphire, and is united to the oxides of iron in the ochres; and also forms a part of the precious stones.

What are the chief uses to which alumine has been applied?

Alumine is employed for various purposes, on account of its aptitude for moulding* into different forms†, and its property of hardening in the fire; such as for making bricks, earthen-ware, porcelain ‡, crucibles, &c. Its uses are so various

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quently contains metallic oxides, chalk and other earths. Alumine united to the oxides of iron, is gotten in great plenty in Staffordshire and Derbyshire; in which state it is called raddle, an article very useful in colour-making. Fullers' earth is alumine combined with very fine silex. It is owing to the affinity which alumine has for greasy substances, that this article is so useful in scouring cloth. Hence pipe-clay is frequently used for the same purpose. Alumine combined with carbon forms that peculiar combustible substance called *anthracite.*

* Stone ware, according to the Old Testament, was known at an early period to the Jews. The making of porcelain has long been known in China and Japan; but it was accidentally discovered in Europe by a chemist, in the beginning of the 18th century. It was so esteemed by the Romans, that, after the taking of Alexandria, a porcelain vessel was the only part of the spoil retained by Augustus. Dr. Thomson, vol. ii. 286.

† Alumine is of inestimable value for securing the bottoms and sides of canals and reservoirs of water, and composes in a great measure those tenacious earths called *arable* soils.

‡ The beautiful colours, which are seen upon porcelain, are given by metallic oxides. Purple is given by gold; red by the oxide of iron; yellow by the oxide of silver; green by copper; blue by cobalt; and violet by manganese.

and important, that we cannot conceive how man could have attained his present degree of civilization, if this earth had not been given him in abundance by Nature.

Is alumine employed in forming any chemical combinations?

Aluminous earth is employed by the dyer and the calico-printer, as a mordant for fixing various colours; and upon the continent it is artificially combined with sulphuric acid, in order to form alum §, though we possess the compound ready formed in its native state.

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§ Alum is generally made artificially in France, where they have not the native sulphate of alumine. Chaptal, a chemist of some eminence in that country, has formed a considerable establishment for the manufacture of this very useful article, and has erected immense buildings for preparing sulphuric acid by the combustion of sulphur, totally different from those usually appropriated to such purposes in England. The sulphuric acid thus prepared, is afterwards employed in the manufacture of this aluminous salt. See Annales de Chimie, tome iii. Repertory of Arts, vol. ii. 134.

In England it is not necessary to form alum by art, as the alum-slate is found in great abundance. It is gotten on the sea coast of the north-east part of Yorkshire, from Whitby to Stockton, a distance of about 50 miles. It is generally found in the midst of the rock. That which lies at a considerable depth is generally considered to be the best. The slate, when gotten, is broken to pieces by the aid of fire, and afterwards further acidified, by being frequently moistened, and by exposure to the air. When the efflorescence has taken place, it is put into lixiviating vessels for the extraction of the salt. The saline liquor is then boiled down to the proper strength for

Why do potters employ a mixture of alumine and silex for earthen-ware?

In making earthen-ware a due proportion of both these earths is necessary; for if alumine* alone were used, the ware could not be sufficient-

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crystallization; previous to which is added a portion of alkali, to saturate the superabundant acid, and to favour the crystallization. Indeed, alum cannot be made without a portion of ammonia or potass, as it is a triple salt. All alum is either a sulphate of alumine and potass, or a sulphate of alumine and ammonia. *Urine* is generally used in Scotland, and sulphate of potass in Yorkshire.

I have been informed, by one of the most considerable manufacturers of alum in this kingdom, that the account of the English alum-works published in 1678, by Daniel Colwall, Esq. corresponds exactly with the present practice. This paper may be seen in the 12th vol. of the Philosophical Transactions, page 1052; and making allowance for the want of chemical knowledge at that period, the account is given in excellent detail.

The first English alum-work was established at Gisborough in Yorkshire, in the reign of Queen Elizabeth, by Sir Thomas Chaloner, who engaged workmen from the Pope's alum-works to superintend it; and kept those workmen till his manufacture was brought to perfection, notwithstanding the bulls and anathemas which his Holiness issued in abundance against him. Beckmann's History of Inventions, vol. i. 316.

One of the most ancient manufactures of alum was at Roche, a city of Syria; whence the name of Roche-alum. See Additional Notes, No. 24.

* For making pottery, or earthen-ware, the alumine is beaten in water; by which the fine parts are suspended in the fluid, while the coarser sink to the bottom of the vessel. The thick liquid is further purified by passing it through hair and lawn

ly burnt without cracking and shrinking too much; and a great excess of silex would lessen the tenacity, and render the ware brittle.

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sieves of different fineness; this is afterwards mixed with another liquor of about the same density, consisting of ground flints. The mixture is then dried in a kiln, and after being beaten to a proper consistence becomes fit for being formed at the wheel into dishes, plates, bowls, &c. When the ware has been exposed to heat for a certain time, it is glazed, or is made to undergo a partial vitrification at the surface, without which it would be pervious to fluids. Ordinary pottery is glazed with a semi-vitreous oxide of lead: what is called stone-ware is glazed by the fumes of muriate of soda; this salt being thrown into the oven during the baking of the articles, which are so disposed as to receive it on every part of their surfaces. The use of salt for glazing this kind of ware was introduced by two labouring men from Holland, about the year 1700.

More than 5000 tons of ground flint are used annually in the Staffordshire potteries. The flint is first burnt, and then ground in water, with mill-stones of chert, to an impalpable powder. Large establishments for this purpose have been formed in the neighbourhood of Burton upon Trent; and many vessels are constantly employed in carrying it from thence to the places where it is used. It is transported in casks, in the wet state in which it is ground.

Yellow or queen's-ware is made of the same substances as common pottery, but a whiter clay is used, and in different proportions. The glazing is also different. It is made by mixing in water, to the consistence of cream, 112 parts of white lead, 24 of ground flint, and 6 of flint-glass. The ware, before it is glazed, is baked in the fire, by which it acquires the property of strongly imbibing moisture; it is then dipped in this composition and quickly taken out. It is afterwards exposed a second time to fire; by this means the glaze it has imbibed is melted, *What constitutes the difference between earthenware and porcelain?*

Porcelain is not esteemed good unless it be very compact*, quite white, and semi-transparent †; indeed, it is chiefly the last quality that

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and a thin glossy coat is formed upon the surface, which is more or less yellow, according as a greater or less proportion of lead has been used. The unfortunate men, who are employed in dipping the biscuit-ware in this composition, soon become paralytic from the effects of the lead; other men are substituted in their room, who are destined to labour under the same malady. Hence, the Society for the Promotion of the Arts, &c. has offered a premium for a substitute for this glaze, or for a mode of using it which would not subject the men to these sufferings.

It is said that a French manufacturer at Moulins, in the department of Allier, has lately discovered a new kind of earthenware, which comes cheap, and is capable of resisting the action of fire and acids. The glazing is purely *siliceous*, and cannot be injured by fatty substances, or by the most corrosive acids.

* Porcelain is an artificial compound of great durability. When good, it is of so compact a texture that it would probably endure for ages. There is an octagon tower at Nan-king in China, called the Porcelain Tower, which is entirely covered with the most beautiful china. It is a building of nine stories, nearly 300 feet high, and each story decreases in breadth, as it rises in height. This singular and elegant edifice still retains its original beauty, though it has sustained the continued action of the sun and weather for four hundred years.

† The perfection to which the manufacture of porcelain has arrived in England is owing to the discoveries of the ingenious and indefatigable Wedgwood, who has left us an admirable ex-

constitutes the principal difference, for earthenware is always opaque.

What is zircone?

Zircone is a peculiar earth, which has been found only in a gem called zircon and the hyacinth of the island of Ceylon ‡.

What are the properties of zircone?

Zircone, when separated from the precious

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ample of what may be effected by peculiar talents and persevering industry. Such investigations as those to which he was accustomed, bring with them their own reward. Such experimentalists

> "Exult in joys to grosser minds unknown,
> A wealth exhaustless, and a world their own."

An interesting account of the processes which are carried on in the great French manufactory of porcelain at Sevres has been published by Brogniart, who superintends it. This paper has been translated, and published in the 13th and 14th volumes of the Philosophical Magazine.

The Chinese are said to let their clay remain exposed to the atmosphere at least 20 years before they use it in making porcelain. Notwithstanding this, I believe the English porcelain now surpasses any that is made in that country. That aluminous earth improves by this treatment there can be no doubt; for tile-makers in England, who are curious in the article they manufacture, never use their clay till it has lain a year or two in the open air.

‡ Zircone was discovered by Klaproth, in the year 1793. The stone from which he procured it came from Ceylon; but the same stone has since been found in various parts of Europe.

A fossil from Greenland, called *compact* hyacinth, has been lately analysed, and found to contain 10 per cent. of zircone.

stones in which it is found, has the form of a fine white powder, destitute of taste and smell. It is soluble in the acids and the alkaline carbonates*, but differs from all the other earths in not being soluble in pure alkalies†. Its present scarcity prevents our employing it to any useful purpose.

Whence do we procure glucine?

The peculiar earth called glucine has been found only in the emerald and beryl, precious stones procured from Peru and from the mountains of Siberia ‡.

What are the properties of glucine?

Glucine, when separated from the stones which contain it, is a soft, light, white powder, without taste and smell; adhesive to the tongue like alumine§; infusible by heat; but soluble in the acids, with which it forms soluble sweet-tasted salts ||, slightly astringent. This earth is not very

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[*] If zircone be heated to whiteness, it is not afterwards soluble in the acids.

[†] If zircone be kneaded with water and gradually dried, it will take the semi-transparent appearance of horn.

[‡] *Glucine* is derived from the Greek word γλυκὺς, *sweet*; which is very appropriate to this earth, as it gives a saccharine taste to all the acids with which it combines.

[§] Glucine is insoluble in water, and soluble in pure liquid alkalies, in which it further resembles alumine; it also agrees with that earth in being insoluble in pure ammonia, though soluble in carbonate of ammonia.

[||] From the sweet taste of the salts of glucine, we have reason to believe that Nature, who forms nothing without its use, plentiful, nor has it yet been employed in the arts¶.

What is the origin of yttria?

Yttria is a peculiar earth* which has been found only in a black mineral from Sweden, called gadolinite; which besides this earth contains iron, manganese, lime, and silex†.

How is yttria to be distinguished?

Yttria, when separated from the mineral, is in the form of a fine, insipid, white powder‡. It

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has endowed this earth with properties which will some time or other render it eminently serviceable to the animal œconomy.

¶ Vauquelin is of opinion that hereafter this earth will be useful as a mordant in dyeing, and that it may be serviceable in medicine when it comes to be discovered in greater plenty. Lelievre announced some time ago, that he had discovered the emerald in stones used for repairing the roads near Limoges in Guienne. From this source a large quantity of glucine might be procured.

* This earth was discovered by Gadolin, a Swedish chemist, in a mineral found at Ytterby in that kingdom. From this circumstance the fossil has been called Gadolinite, and the earth Yttria.

† There is some reason for supposing that yttria may be a metallic oxide. A foreign chemist has lately announced, that when muriate of yttria is heated to redness it gives out oxygenized muriatic acid.

Mr. Davy suspects that yttria and glucine are not distinct *primitive* earths, but modifications of other earths.

‡ The specific gravity of yttria is 4.842, which approaches nearer the specific gravity of metals than any other earth. It has therefore been said to be the link which connects the earths with the metals.

forms sweet and coloured salts with the acids, is insoluble in the caustic alkalies, but easily dissolved in a solution of carbonate of ammonia[*].

What is the origin of barytes?

Barytes was discovered by Scheele in combination with sulphuric acid, in a mineral called ponderous spar, afterwards terra ponderosa[†]. It is chiefly found in this state in England, and in other parts of the globe.

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[*] Though yttria is insoluble in the alkalies, and infusible alone, it may be fused when mixed with borax, and forms a white glass with that salt.

[†] Barytes was discovered by Scheele in 1774. It is always found united either with the sulphuric or the carbonic acid. The best method of procuring this earth pure for chemical purposes, is, to dissolve the carbonate of barytes in very weak nitrous acid, by which means the carbonic acid will be expelled, and then in the usual way, by proper evaporation, crystals of nitrate of barytes will be formed. By exposing this salt to a strong heat, the nitric acid will be dissipated, and pure barytes will be left in the crucible. See Fourcroy and Vauquelin's memoir in the Annales de Chimie, xxi. 276.

Sulphuric acid is the best test for the presence of this earth.

Bergman gave it the name *barytes* from the Greek word *βαρὺς*, *heavy*, this being the most ponderous of all substances except the metals.

Sulphate of barytes is very plentiful in the Derbyshire lead mines: the workmen call it cauk. For a description of this mineral, consult Thomson's Chemistry.

A method of crystallizing this earthy salt artificially was pointed out by Withering, in the Philosophical Transactions for 1784.

Casciarole, an Italian shoemaker, discovered that if sulphate

Is this earth found in any other states?

Yes: it occurs in Northumberland, Cumberland, and Lancashire, in large masses combined with carbonic acid[‡]; and also in France in combination with the oxide of manganese.

What are the properties[§] *of barytes?*

Barytes is of a grayish white colour; it changes the vegetable blues like alkalies[||], has a pungent

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of barytes be calcined in a peculiar way it will acquire a phosphorescent quality, and will shine even in water. It is known by the name of Bologna phosphorus. For the method of making it, consult Bouillon La Grange, vol. i. 188; or Nicholson's Chemical Dictionary.

Several of the natural gems and fossils exhibit phosphorescent properties by attrition. In the tremolite this property is so abundant, that the slight friction of a feather is of itself sufficient to excite it.—*Murray*.

[‡] Carbonate of barytes was first discovered by Dr. Withering of Birmingham, in the lead mines of Alston Moor, Cumberland; and for a long time afterwards it was found only there and at Anglezark, three miles to the east of Chorley, in Lancashire. Some of the specimens have much of the appearance of sulphate of alumine. See Dr. Withering's paper in the Philosophical Transactions for 1784.

[§] Pure barytes changes quickly when exposed to the air; it swells like quick-lime, and like it falls into a white powder; but this slacking is much more violent and speedy than that of lime. It combines intimately with water, by which combination the water becomes solidified.

[||] Barytes is also similar to the alkalies in changing *red* vegetable colours to a violet or blue, and *yellow* vegetable colours to a brown; in rendering oil miscible with water; in forming glass with silex; in its solubility in water; and in the readiness with which it shoots into crystals.

caustic taste, and is a violent poison. It may be known from the other earths by its solubility in water[*], by its forming an insoluble compound with sulphuric acid[†], and by its tingeing flame yellow. Its specific gravity is 4.00.

What are the uses[‡] of barytes?

It forms some of the most useful chemical tests[§], whether in its pure state dissolved in water, or combined with particular acids: in muriatic acid also it is employed as a medicine. It is capable of making a very tenacious cement, but

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[*] Boiling water will dissolve half its weight of this earth, part of which will crystallize on cooling.

[†] The most singular property of this earth is the tenacity with which it holds the sulphuric acid when combined with it. It has such an affinity to it, that it will not part with it even to pure alkalies. Hence pure barytes will decompose sulphate of potass or sulphate of soda.

[‡] Barytes has been proposed as a medium for decomposing muriate of soda in a cheap way. If ever the carbonate should be found in as great masses as the sulphate of this mineral, it might be employed for this purpose. The method of using it may be seen in the Annales de Chimie, tome xix. See also a paper of Vauquelin's on this subject in Journal de Phys. 1794, p. 297.

[§] The solution of this earth in water, and in various acids, furnishes excellent tests for chemical analysis. The muriatic acid is often preferred, especially for medical purposes, such as scrophulous and some other chronic diseases. Though this earth has been accounted highly poisonous, yet Dr. Johnstone says that he has seen a delicate female take thirty drops of a saturated solution of muriate of barytes *repeatedly* in the course has not yet been used much in the arts, except as a most excellent water colour [||].

What is the origin of strontian?

Strontian was first discovered about the year 1787 in a mineral brought from the lead-mine of Strontian in Argyleshire. That mineral is a *carbonate* of strontian; and, as yet, has been found but in small quantities in any other place [¶].

Is this earth found in any other state?

Strontian combined with sulphuric acid has been found in various parts of the world, particularly near Bristol; where it is gotten in such abundance as to be employed in the repairs of the neighbouring roads[*].

What are the properties of strontian?

Strontian, when separated from its acid, is, like barytes, soluble in water; it is of a grayish white

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of a day, without even nausea. He therefore concludes that it would require at least 2 or 3 drachms to do mischief.—Essay on Poisons, 143.

[||] Many years ago Mr. Hume discovered the method of making a colour from this earth. It is the only *white* for water painting, that never changes. It has another peculiar advantage, it may be mixed with any other colour without injury.

[¶] See Pelletier's paper on this earth in the Annales de Chimie, tom. xxi. 113; and in Nicholson's Journal, 4to. vol. i. 518.

[*] See Nicholson's Journal, vol. iii. 36. Sulphate of strontian is also found in great plenty on the roads near Paris, and in the province of Pennsylvania in America.

colour[*]; its taste is acrid and alkaline, but less so than barytes or the alkalies. It is not poisonous; and its solution in water is capable of crystallization[†]. It gives a purple colour to flame[‡], which is the chief characteristic that distinguishes it from barytes.

What are the uses of strontian?

Strontian, though it combines readily with all the acids and possesses alkaline properties, has not hitherto been employed for any useful purpose[§]. Hereafter it may be found to possess valuable properties, for it exists in abundance, and the Author of Nature has formed nothing in vain[‖].

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[*] In order to procure this earth in a state of purity, carbonate of strontian may be treated in the same way as carbonate of barytes. See page 158.

[†] Strontian is not soluble in less than 100 parts of cold water; hot water dissolves it much easier; it then crystallizes on cooling, and is similar to barytes in many of its habitudes.

[‡] If moisture be present in the mixture of strontian with inflammable bodies, the flame will be of the colour of carmine. Thus, if this earth, or the salts formed with it, be dissolved in alcohol, the spirit will burn with a flame of this colour. This distinguishes it from barytes.

[§] It will be advisable for the preceptor to procure specimens of this and other minerals, that the pupils may learn how to distinguish them. It will also serve to give a variety to the lessons, and prevent satiety.

[‖] I have been informed that an eminent physician, I believe Dr. Pearson, has recommended this earth as an *absorbent* to correct acidity in the stomach, when magnesia would prove too aperient.

How is lime to be distinguished from the other earths ¶?

Lime is of a white colour, and of a hot caustic taste; it forms peculiar salts with acids *, which is perhaps the most delicate proof to identify any earth or other simple substance: it changes vegetable blues to a green; is incapable of fusion; gives out a great quantity of caloric when sprinkled with water †; and absorbs carbonic acid when exposed to atmospheric air ‡.

¶ The specific gravity of pure lime is 2.3. It is soluble in 300 parts of water.

* Lime forms with sulphuric acid a compound soluble in water to a certain degree; so that this earth is easily distinguished from barytes and strontian, whose sulphates are insoluble.

† Quick-lime has such an affinity to water that it will absorb one fourth of its weight of that fluid, and yet remain perfectly dry. The water becomes solidified and identified with the earth. The heat therefore that is evolved in the process of slacking lime, proceeds from the water as it passes to the solid state, and not from the earth as is generally supposed.

‡ The effect of carbonic acid upon lime may be shown by the following experiment: Add gradually a very small quantity of water, impregnated with carbonic acid, to a jar about one-fourth filled with lime-water. A milkiness will ensue, because the carbonic acid forms with the lime an insoluble compound. On adding more of the carbonated water, and shaking the jar as these additions are made, the milkiness at last disappears, and the whole precipitate becomes re-dissolved. Hence it appears that lime, with a *small* quantity of carbonic acid, is insoluble, and soluble with a *larger* quantity.

It is thus that Nature dissolves and deposits calcareous

In what state is lime found in nature?

Pure lime is never found native; it is always in a state of combination, generally with an acid, and most copiously with carbonic acid, as in chalk, marble, limestone, &c *. It is found also

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masses. When the waters, by their exposure to the air, lose that quantity of carbonic acid which favoured the solution of the lime, deposits are formed; and hence the stalactites and incrustations found in caverns, &c., and even the foliaceous calcareous strata of rocks; which, without doubt, have in some period been held in solution. When these waters *suddenly* lose the acid which was essential to the solution, there is an *irregular* precipitation: hence those tender calcareous cellular stones, and perhaps also the spongy tufts; but if the evaporation of the carbonic acid takes place slowly, it produces crystallizations, such as stalactites, &c. When lime is crystallized by nature in combination with acids, it is called *spar*. With fluoric acid it forms the beautiful Derbyshire spar, called blue John. With carbonic acid, the dog-tooth spar, the Iceland crystal, &c.

* The vast mountains of calcareous earth which are found in different parts of the world, owe their origin, in general, it is supposed, to the destruction of marine testaceous animals, which in long process of time formed such vast accumulated heaps.

"For in vast shoals beneath the brineless tide,
On earth's firm crust, testaceous tribes reside:
Age after age expands the peopled plain,
The tenants perish, but their cells remain;
Whence coral walls, and sparry hills ascend
From pole to pole, and round the line extend."—Darwin.

Fourcroy, in his Chemical Elements, has given a beautiful account of this process of Nature, to which I refer; as I am in vegetables, and is the basis of animal bones.

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persuaded every reader of taste must be charmed with its perusal. See Thomson's edition, part iii. chap. 7, sect. 1.

According to Captain Cook, there are in the Southern Ocean perpendicular coralline rocks, formed entirely of sea-shells, which are of such magnitude as to render the navigation of those seas extremely dangerous.

The shells of some testaceous animals in the South Sea are extremely large. The *kemo* shell on the coast of Sumatra is frequently found 3 or 4 feet in diameter, and as white as ivory. See Marsden's History of the Island of Sumatra, page 10.

It may be remarked, that while *testaceous* shells are formed with carbonate of lime, the shells of *crustaceous* animals and the shells of birds' eggs contain also a portion of phosphate of lime. Its use in the former is not known; but the design of Nature in furnishing the shells of eggs with phosphoric acid is very apparent. The body of the egg contains neither phosphoric acid nor lime: it was necessary therefore that Nature should provide means of furnishing both these substances, which it does at the expense of the shell; which becomes thinner and thinner during the whole time of incubation, till the living embryon hath appropriated a sufficient quantity for the formation of its bones. Part of the albumen for this purpose combines with the shell, and another portion forms feathers, &c.

One thousand parts of egg-shells are composed of

Carbonate of lime .	896
Phosphate of lime .	57
Gluten and moisture	47
	1000

If fowls are kept in a state of confinement where they cannot get at any calcareous earth, they lay their eggs without shells.

It occurs likewise in the water of the ocean, and indeed in that of all springs and rivers*.

How is pure lime procured from these minerals?

Carbonate of lime, by whatever name it is called, whether chalk, marble, limestone, oyster-shell, &c. is to be broken into convenient pieces, and piled with coal stratum super stratum in kilns, where it is kept for a considerable time in a *white* heat. By this means the carbonic acid and water are driven off, and tolerably pure lime is the product †.

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* This earth is dissolved in such quantities in the waters of Tuscany, that the artists there are said to form *basso relievos* of very considerable hardness, merely by filling their moulds frequently with the chalky waters of the baths of St. Philip.

† *Pure* lime should always be kept in well stopped bottles, if for nice experiments: without this precaution it would soon absorb carbonic acid, and become carbonate of lime. If lime-water be exposed to the air, it soon becomes covered with a pellicle of carbonate of lime from the same cause. In like manner, if a little lime-water be put into a glass syphon, and the legs of the syphon be held upwards so that a person might blow through it without the liquor running out, the breath will be found to give a milky colour to the lime-water, and carbonate of lime will be seen forming at the bottom of the liquor, which will effervesce with acids, and have every chemical quality that it had when in the quarry. This change is owing to the absorption of carbonic acid from the lungs.

Some persons who have occasion for lime of the *best* quality, may be glad to be informed that the earl of Stanhope has established a work on a new principle for the express purpose of furnishing this useful article in greater purity than it can be had elsewhere.

What are the chief uses of lime?

Lime united with the acids is applied to various useful purposes, and, next to silex, forms a material portion of the solid fabric of the terrestrial globe ‡. In a *separate* state it is used in many of the arts §, particularly in making mortar for buildings. Also by farmers as a manure; by bleachers ||, tanners, sugar-bakers, soap-boil-

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Bishop Watson found by experiment that upon an average every ton of limestone produced 11cwt. 1qr. 4lbs of quick-lime, weighed before it was cold; and that when exposed to the air it increased in weight daily at the rate of a hundred weight per ton for the first five or six days after it was drawn from the kiln. This fact is worth the notice of those farmers who fetch their lime from great distances.

In the Journal de Physique for 1775, page 311, are a plan and description of a kiln for calcining lime *after* it has been reduced to powder, in order that it might be used quite hot without the necessity of its being slacked by water. For some purposes this is found to be very advantageous.

‡ The inhabitants of towns and houses built on a chalky or limestone foundation are observed to be less liable to infectious or epidemic disorders than those of any other situation.

§ Quick-lime well dried and pulverized is said (by the French translator of Mr. Henry's Epitome of Chemistry) to increase the explosive effects of gunpowder, when mixed with twice its weight of the latter.

Lime is used in the manufacture of glue. The design of it is to prevent its becoming flexible by the absorption of moisture, and to add to its strength. Some persons use alum for the same purposes.

|| Quick-lime was used by the antients for bleaching. Theophrastus, the disciple of Aristotle, and who wrote more than

ers, iron-masters *, and others, in their several manufactories, and in medicine †.

How do you explain the operation of lime in forming mortar and cements?

Pure lime has, when united to a certain portion of water, a very strong affinity for silex, another most essential ingredient in mortar and cements; for without this it never hardens—but when mixed in proper proportions, the whole crystallizes as it gradually imbibes carbonic acid from the atmosphere, and thus in a series of years becomes as hard as unburnt lime-stone ‡.

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300 years before Christ, speaks of it in this connection. He relates an instance of a ship which was loaded in part with linen, and in part with quick-lime, having been set on fire by water that was accidentally thrown over the latter, which fired the linen, and occasioned the destruction of the vessel.

* The iron ores that are wrought in this country contain a large portion of alumine and silex: in order therefore to flux these earths and more effectually separate the iron, a quantity of lime is usually mixed with the ore in the furnace; lime having the property of rendering the other earths more fusible.

† Lime has the property of seizing oxygen from the atmosphere—hence the unhealthiness of rooms newly white-washed. Parkinson.—The design of Nature in giving this property to lime is not as yet apparent.

‡ When lime is made into mortar, it takes a long time in acquiring the portion of carbonic acid which it possessed in the quarry; but the mortar hardens as this absorption takes place. This accounts for the great strength of some ancient buildings, in which the mortar is found to have a greater degree of firmness than even limestone itself.

How does lime act so as to be of use as a manure for land?

The use of lime in agriculture may be attributed to a property of hastening the dissolution and putrefaction of all animal and vegetable matters §, and of imparting to the soil a power of retaining a quantity of moisture necessary for the nourishment and vigorous growth of plants, corn, &c.||: but there is no good soil that does not contain a certain portion of lime, though always, without exception, combined with carbonic acid.

The sand which is mixed with lime to form mortar or cement, serves a purpose similar to what is answered by sticks put into a saline solution to favour its crystallization: therefore, the harder and sharper the sand, the better; for, if the matter interposed between the crystals be of a friable nature like chalk, the mortar must be weak. See Additional Notes, No 20.

§ For a further explanation of this chemical process, see Anderson's Essays on Agriculture; he thinks that no quantity of lime can possibly be too great for land.

|| Hence lime and chalk are found to be particularly useful on sandy soils. Marle is a mixture of carbonate of lime and clay. See Additional Notes, No. 20. Marles are useful in agriculture only in proportion to the calcareous earth they contain. Unless they contain more than 30 per cent. of lime they are of no value to the farmer. Of all the modes of trial, the one best suited to the unlearned farmer is, to observe how much *fixed air* the marle gives out; and this he will learn by dissolving a little of it in diluted muriatic acid, and observing what portion of its weight it loses by the escape of this air. Thus, if an ounce loses only 40 grains, he may conclude that

What is the use of lime in the operation of tanning leather?

Lime is used by the tanner in a state of solution; in this the hides are immersed in order to dissolve the gelatinous part of the skin, and to facilitate the removal of the hair*.

How is lime used in refining sugar?

By boiling the sugar in lime-water the manu-

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the ounce of marle contained only 100 grains of calcareous earth, and that it would be his interest to pay seven times as much for a load of lime as he must pay for a load of marle at the same distance. Dr. Black's Lectures, vol. ii. 120.

Every farmer should ascertain the *nature* of his lime before he uses it in agriculture, as there are many extensive districts in England where the lime is contaminated by magnesia, which renders it injurious to the growth of vegetables. See Mr. Tennant's paper on this subject in the Philosophical Transactions for 1799. The limestone of Breedon in Leicestershire is found to contain half its weight of magnesia. Darwin's Phytologia, 211.

Magnesian limestone is generally of a fawn colour, but it may be known by its being ten times as long in dissolving in an acid as common limestone. This is the lime which the Yorkshire farmers call *hot* lime.

* The theory of tanning is shortly this: After the impurities of the skins are removed, they are steeped in an infusion of oak-bark, which consists of two distinct substances, viz. the gallic acid, and the tanning principle. The gallic acid deprives the skins of their oxygen in a gradual manner; and while this is taking place the tan combines with the fibrous part, and forms leather. See Seguin's paper on the improved modes of tanning in Nicholson's Journal, 4to. vol. i. 271; also Professor

facturer deprives it of a certain uncombined acid[†] which prevents crystallization[‡].

What is the use of lime in the manufacture of soap?

Lime is mixed with the alkali in order to deprive it of carbonic acid. The alkali is thus rendered what is called *caustic*, and in this state operates more powerfully on the oil or tallow which is to be converted into soap[§].

Davy's paper on this subject in the Philosophical Transactions, vol. xciii. 233.

[†] Lime is frequently used by chemists in processes where there is a superabundant and injurious quantity of acid. The lime seizes the acid, and frees the solution from it, by forming with it a neutral salt.

[‡] For the process of refining sugar in England, see Rees's Cyclopædia—article *Sugar*. The account may be relied on, as it was written by a gentleman engaged in the business. The method of refining in the French South American colonies is described by Fourcroy, vol. vii. 215.

Dr. Roxburgh has lately published a minute account of the Hindu method of cultivating the cane, and manufacturing the sugar, in the *Asiatic Annual Register* for 1802.

[§] As different alkalies require different proportions of lime to render them perfectly caustic, every soap-maker should be acquainted with a test by which he may ascertain when he shall have given the proper quantity.

Having paid great attention to the different processes in this manufacture, I think I am justified in saying, that no trade is less understood, even by the people who conduct it, than this. At some future time I intend (if other avocations admit of it) to draw up a treatise on the manufacture of soap, in which I shall endeavour to explain the different operations on chemical

We have hitherto spoken only of lime, and of carbonate of lime: Is lime found native in any other state of combination?

This earth exists in large quantities in various parts of the world combined with sulphuric acid, which forms gypsum*; with the fluoric acid in the fluor spar†; with the phosphoric acid in a mineral called *apatite*‡, and in some precious stones.

What is magnesia?

Magnesia is a very soft, white, light earth;

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principles, and how each process may be conducted to the best advantage. We have no *English* work on soap-making, and I believe there is nothing in any language worth reading on this subject except the "Report on the Fabrication of Soaps, made by Darcet, Lelievre, and Pelletier, by order of the Committee of Public Safety," in the 19th volume of the Ann. de Chimie; but as the French make use of articles which our soap-makers cannot avail themselves of, a great part even of that paper is not applicable to the practice in this country.

[*] Gypsum is composed of 30 parts of sulphuric acid, 32 earth, and 38 water. Kirwan.

[†] Lime combined with the fluoric acid forms those beautiful fluor spars which are brought from the mines of Derbyshire. Combined with muriatic acid, large quantities of this earth are held in solution by the waters of the ocean.

[‡] The bones of all kinds of animals are formed of this earth and phosphoric acid, in the proportion of about 80 parts earth and 20 parts acid.

The best test for the presence of lime is oxalic acid, which forms with it an insoluble precipitate. Oxalate of ammonia is generally used for this purpose.

with little taste or smell§; unalterable in the fire||, and almost insoluble in water¶; and when combined with sulphuric acid forms a purgative salt very easy of solution*.

How is magnesia procured?

Magnesia is never found in a state of purity, but is generally procured from sulphate of magnesia (Epsom salt†) which exists with the muriate of this earth in sea-water, and in many

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§ Magnesia converts vegetable blues to a green. In this respect it resembles the alkalies. Indeed some chemical writers have classed it with the alkalies. It was formerly confounded with carbonate of lime: Hoffman was the first who distinguished it from all other earths.

|| Though this earth is infusible of itself, it assists the fusion of every other body. It requires near 8000 times its weight of water to hold it in solution: notwithstanding this, it has the property of rendering camphor, opium, and resins, soluble in water. Its specific gravity is 2.33.

¶ Magnesia dissolves in alkaline carbonates, but is not soluble in the caustic alkalies.

* Sulphate of magnesia is found in several mineral waters. The *bitter* saline waters generally owe their taste to this salt. All the salts formed with this earth are bitter, and generally very soluble.

The Epsom salt (sulphate of magnesia) of commerce is generally procured from the mothers which remain after the separation of common salt from sea water, by adding thereto sulphate of iron. In this process the sulphuric acid leaves the iron to unite with the magnesia, and the muriatic acid which was before combined with it unites with the iron.

† The magnesia used in medicine is prepared thus: A solution of carbonate of potass, or soda, is poured into a heated solution of sulphate of magnesia, when a double decomposition

springs. Magnesia is also a component part of several minerals*.

What are the uses of magnesia?

Pure magnesia, as well as the sulphate and carbonate, has important uses in medicine†. It is also required in some chemical processes, and is employed by the manufacturers of enamels and porcelain‡. It is also the most effectual antidote in case of poison by the mineral acids§.

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and combination take place. The sulphuric acid of the sulphate of magnesia seizes the alkali, and the carbonic acid of the alkali combines with the magnesia. Thus carbonate of magnesia and sulphate of the alkali result from the process.

* Inverary-House is built with a stone called lapis ollaris, which contains a large portion of magnesia. Magnesia is found also in talc, steatites, potstone, asbestus, fossil cork, and other minerals. The stones which contain a large portion of this earth have generally an unctuous feel, a fibrous texture, and a silky lustre.

† When magnesia is taken as an aperient, it ought to be in the state of carbonate of magnesia, or what is called mild magnesia. When it is taken as an absorbent to correct acidities, calcined or caustic magnesia is most proper. On several accounts it is of consequence to attend to this distinction.

‡ It is probable that some of the most esteemed of the porcelain clays may owe their estimable properties to an admixture of magnesia. In Nicholson's Journal, vol. xii. we read of a porcelain earth, hitherto considered pure clay, having been analysed, and found to consist only of carbonate of magnesia and silex. Magnesia, I understand, is of use in porcelain, by lessening the degree of contraction to which all kinds of earthen-ware and porcelain are liable.

§ If putrid water be agitated with a small quantity of mag-

Are there not instances in nature of the earths entering into combination with each other ||?

Yes: minerals are found, in which the earths are combined in different proportions by processes unknown to us, which Nature employs to produce that endless variety of what, in common language, we call rocks, stones, gems, &c.¶

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nesia, it will lose its bad taste and smell in a few minutes. Proust, Journal de Physique. Might not this method be sometimes of use at sea, on long voyages?

|| Alumine and silex are the earths which have the greatest affinity. These earths are found in nature oftener united than any other. The hardest stones are formed of these two earths.

Monsieur Guyton de Morveau has proved by direct experiment that the earths have not only an affinity for each other, capable of producing combination, but likewise an elective attraction, which destroys one compound in order to form another. The paper containing an account of his experiments may be seen in Annales de Chimie, tom. xxxi. Mr. Chenevix's memoir on this subject, in the Phil. Trans. for 1802, is also very interesting.

¶ Potter's clay is a mixture chiefly of silex and alumine; the colouring earths used as pigments are mixtures either of clay and the oxides of iron, or clay and charcoal; garden mould is a mixture extremely various, sometimes containing silex, alumine, magnesia, iron, lime, and carbon; the common millstone is generally composed of alumine and silex; and the crumbling sandstone is a mixture of iron and silex. It is however impossible to enumerate the endless diversity of substances which Nature offers ready formed for the use of man; for the mixtures of the earths which are found *naturally* combined, comprehend all the varieties of clays, slates, stones, spars, gems, rocks, crystals, zeolites, quartz, flints, &c.

What do you suppose could be the design of Nature in forming so many distinct earths?

The earths have several properties in common; yet as every earth possesses different and specific properties, it is evident that Nature designed them for different and distinct purposes of utility.

You have enumerated the separate uses of most of the earths; can you recollect the collective advantages which arise from this class of bodies?

The uses of many of these earths are not yet discovered; but the benefits which we derive from lime, clay, silex, and magnesia are too various and important to be enumerated. Besides

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The student may acquire much information on this subject from Weaver's Translation of "Werner's external Characters of Fossils," 8vo.

A regular classification of the different earths and stones, according to the system of M. Daubenton, may be seen in the first volume of Thomson's Fourcroy.

A few short directions for analysing stones are given in Mr. Parkinson's Chemical Pocket-book, new edition, page 216. There is an excellent paper on this subject in vol. iv. of Dr. Thomson's System of Chemistry, p. 128. Fourcroy's directions are more concise, but they are worth the perusal of those who are not accustomed to this kind of analysis. Further information may be had by consulting the 1st vol. of Kirwan's Mineralogy.

The minerals, which are generally the subject of analysis with chemists, are formed with different proportions of the nine earths and the metallic oxides; such as oxide of iron, copper, nickel, manganese, chrome, &c.

that these afford support to the vegetable creation, they possess so many valuable properties, that man may attain a very high degree of civilization, &c., by their means.

In order to impress your memory, and to finish the consideration of this class of bodies, endeavour to recollect those uses of the earths which appear to you to be most important.

LIME, then, has an extensive and important use in agriculture*; it is employed in building, &c., and adds much both to the neatness and durability of our dwellings. SILEX is the basis of all mortar and cements, and is a necessary ingredient in earthen-ware, porcelain, and glass. BARYTES is employed in chemical laboratories as a re-agent, and for the formation of salts. MAGNESIA, besides being the basis of several salts, is of great use in medicine; and ALUMINE, by a due mixture with silex, is capable of forming vessels for chemists that will resist the action of the most concentrated acids; it is the material of which the bricks are formed which construct the walls of our habitations, and is also spread out by the great Author of nature in strata within our hills

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* The goodness of a soil depends upon its being able to retain the quantity of moisture which is proper for the nourishment of vegetables, and no more. Now the retentive power of a soil increases with the proportion of its alumine, lime, or magnesia; and diminishes as the proportion of its silex increases. Dr. Thomson, vol. iv. 9, first edition.

and mountains *, to arrest the progress of subterraneous waters, and to produce those springs that fertilize the valleys, and which take such diversified courses upon the surface of the globe.

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* Some have imagined that the earth would have had more beauty, and would have been much more convenient, if the whole had been a plane surface; and others have gone so far as to adduce the mountainous parts of the world as a proof of the imperfection of the works of Nature: but, independent of the beautiful *variety* which they give to the surface of the globe, they are the sole cause of all our springs, and the origin of rivers, without which we have a difficulty in conceiving how animal and vegetable life could have been preserved.

Like the good man who, elevated by his rank, virtues, and talents, stands erect in conscious integrity, and dispenses blessings of every kind around him—the hills raise their towering heads towards heaven, to draw from thence the fructifying waters, which, when purified by percolation through their siliceous beds, they pour forth in a thousand streams to fertilize and bless every region of the earth.

“ I see the rivers in their infant beds!
Deep, deep, I hear them, lab'ring to get free!
I see the leaning strata, artful rang'd;
The gaping fissures to receive the rains,
The melting snows, and ever-dripping fogs.
Strow'd bibulous above, I see the sands,
The pebbly gravel next, the layers then
Of mingled moulds, of more retentive earths,
That, while the stealing moisture they transmit,
Retard its motion, and forbid its waste.” THOMSON

When we consider that the crystal spring and the meandering river owe their origin entirely to these eminences dispersed over the earth's surface, what importance do the mountains acquire in our estimation! and what reason have we to admire the wisdom of that Being who had an eye to every exigency, and in the infinity of his power has so amply provided for all!

CHAP. VI.

OF ALKALIES.

What is the nature of an alkali?*

The alkalies† have an acrid and urinous taste; they change the blue juices of vegetables to a green; and have the property of rendering oils miscible with water. They are incombustible, but may be rendered volatile by a great heat. They are soluble in water; form various salts by

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* No written description that can be given of an alkali will convey any correct idea of the taste or properties of this class of bodies, to a person who has had no opportunity of examining an alkali: let the pupil therefore procure a specimen of each kind before he enters upon this chapter. The juice of the gooseberry and the lemon, and many other vegetable substances will remind him of the general properties of the acids; but having met with nothing analogous to the alkalies, it will be necessary for him to *taste* and examine one of these bodies in order to acquire any thing like a just idea of their nature. Let him form potass or soda into a neutral salt by saturating it with one of the acids, and he will perceive still more of the nature of these bodies.

† The word alkali is of Arabian origin, and signifies the "dregs of bitterness."

combination with acids[*]; and act as powerful caustics[†] when applied to the flesh of animals[‡].

How many alkalies are there?

There are three alkalies[§]; two of which have been called *fixed* alkalies, the other has long been known by the name of *volatile* alkali.

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[*] Potass becomes mild by its union with carbonic acid; the most caustic soda, if united to corrosive muriatic acid, forms the mild salt used at our tables.

[†] It seems that causticity depends on chemical affinity, and that the caustic substance corrodes the matter to which it is applied, in consequence of its tendency to *unite* with that matter; and that it continues to act upon it until it has saturated itself by the combination. Thus the most caustic alkalies may be combined so as to form insipid salts. See Macquer's Chemical Dictionary, where this chemical operation is very fully explained.

[‡] If a piece of animal flesh be put into a strong solution of potass or soda, it will immediately be acted upon by the alkali, and will soon be entirely dissolved, so that the whole will appear as one mass.

[§] The alkalies have a great affinity for water and for carbon; it is therefore probable that their causticity is owing to this circumstance, water and carbon being so abundant in animal bodies. If the alkalies be dissolved in a large portion of water, they lose their caustic qualities.

The French chemists have classed barytes, strontian, lime, and magnesia among the alkalies, on account of their possessing some alkaline properties; but as they bear a greater resemblance to the earths than the alkalies, I have adhered to the old classification of these bodies.

Which are the fixed alkalies?

The fixed alkalies are potass[||] and soda[¶].

Why have they been called fixed[*] *alkalies?*

Because they will endure a great heat and still remain unchanged.

What substances enter into the composition of these alkalies?

The fixed alkalies have hitherto been considered as *simple* substances, chemists not having yet been able to decompose them; but there are reasons to believe that they are compound bodies[†].

[||] Modern chemists call the pure vegetable alkali *potass*, whereas the article of commerce is called *potash*.

This alkali was formerly procured by burning vegetables in large iron pots; hence it acquired the name of *pot*ash.

[¶] Soda acquired its name from the plant *salsola soda*, which grows on the Spanish coast, and which is burnt for its preparation.

[*] Mr. Chenevix objects to the name *fixed* alkalies; but as the term is used in all modern chemical writings, and as I conceive that it may be useful to assist the memory of beginners, I have retained it in this work. These alkalies have surely some claim to the title of *fixed*, for they require a red heat to dissipate them; whereas the other alkali becomes volatile at a very low temperature.

[†] Some time ago Guyton de Morveau imagined that he had discovered the composition of the fixed alkalies, and announced the discovery to the National Institute: but Darracq repeated the experiments of Guyton, and pointed out the fallacy of his conclusions.

At the great explosion of the iron furnace at Colebrook Dale

Have we any historical account of the discovery of these substances?

Potass was known to the ancient Gauls and Germans[*]; and soda was familiar to the Greeks and Hebrews. This latter substance was known to these ancients by the name of nitrum[†].

What is the origin of potass?

Potass is chiefly procured by lixiviation from the ashes of burnt wood, and other vegetable substances[‡]; but as it exists in minerals and

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by the bursting of the dam of the river, on the 7th of September 1801, its whole contents were thrown into the air, and it is said nothing was found afterwards but potass, soda, and prussiate of potass.

It has been ascertained by experiment that potass is formed in what are termed nitre-beds, or collections of the materials from which nitre is procured, though it could have pre-existed in none of them. How this takes place we certainly at present are quite ignorant.

[*] These people were probably the *inventors* of soap, as we are told by Pliny, that they made soap with the ashes of vegetables and tallow. A soap-boiler's shop with soap in it was discovered in the city of Pompeii, overwhelmed by Vesuvius, A. D. 79. See Miss Starke's Letters from Italy.

[†] This substance is found native in Egypt, and is there called *natron*; a name not much unlike that which it bore among the Jews and Greeks.

[‡] A table of the quantities of alkali procured from different kinds of wood, may be seen in a valuable memoir on the fabrication of potash in Annales de Chimie, tome xix. 157. Directions, by Vauquelin, for burning vegetables in a proper manner for this purpose, will be found in the same volume, 194.

earths§, there is reason to believe that plants receive it from the earth during vegetation‖.

What is the origin of soda?

Soda is generally procured from the ashes of *marine* plants¶; but its great depository is the

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Potass is prepared in large quantities in wine countries, by the incineration of wine-lees and must. This article is known in France by the name of *cendres gravelées.*

§ Potass has been discovered in the pumice-stone; in the zeolite; and in the leucite, an earth of the siliceous kind. It has also been found in the aluminous ores of La Tolfa; but never in an *uncombined* state that I know of, except in the water of some wells.

‖ It has been said, that potass cannot be procured from vegetables without burning them *previously* to their being lixiviated, or treating them with nitrous acid, or by some process capable of furnishing oxygen and nitrogen; and, indeed, it has been found, that if vegetables be soaked for some time in water and then burnt, they will afford no potass. Hence it appears that potass, or one of its constituent parts, exists in the plants before incineration. It is therefore probable that the potash was originally in the *soil,* and that the vegetables take it up by their vegetating organs.

¶ The *salsola soda,* which grows among the cliffs on the sea coast, is endowed with the property of decomposing sea-salt. By some process of vegetation, it separates the muriatic acid and absorbs the soda. Hence it acquired the name of *saltwort.* This plant is collected by the Spaniards with great care, and burnt for the manufacture of BARILLA, which is a considerable article of commerce. Thus Nature has providently furnished the inhabitant of the otherwise barren coast with a source of employment, and has enabled him to supply the interior with an article of indispensable necessity, for ages before the science ocean, soda being the base of sea-salt*, or muriate of soda.

How is it that marine plants give out soda, while those which grow in the interior of the country afford potass?

This can only be accounted for by supposing

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of chemistry could afford him other means of decomposing muriate of soda.

> " The *saltwort's* starry stalks are thickly sown,
> Like humble worth, unheeded and unknown."
> CHARLOTTE SMITH.

Most of the peasantry in the Shetland Isles and in the Highlands of Scotland are supported by collecting sea-weeds, and burning them into KELP, an article which produces great revenues to the lairds of those districts. Many of the wretched inhabitants of those dreary regions have nothing to depend upon for subsistence, but a miserable pittance, which they acquire in this employment.

> " The kind impartial care
> Of Nature nought disdains; thoughtful to feed
> Her lowest sons."

The best account of the manufacture of kelp will, I believe, be found in Jameson's Mineralogy of the Scottish Isles. See also Repertory of Arts, vol. xii.

Soda, combined with carbonic acid, is found mixed with earth in Hungary, Bohemia, and Switzerland; also in China, Syria, Persia, and India.

* Soda is procured also by chemical processes from sea-salt, which is found in immense masses under the earth's surface in many countries, particularly in Poland, Hungary, Spain, and England.

An interesting memoir on the decomposition of this salt, published by order of the Committee of Public Safety, may be seen in the Annales de Chimie, tome xix. 58. It occupies 98 that vegetables have the power, during vegetation, of decomposing sea-salt, and retaining the soda in their constitution.

Is soda found in any other state?

Yes: soda is found in great plenty combined with carbonic acid in the natron beds of Egypt†,

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pages, and contains a detailed account of several effective processes. It may perhaps be the means of saving some individuals from loss and disappointment, if I inform them, that I have myself repeated most of those processes in a reverberatory furnace, built for that particular purpose, capable of producing an intense heat, and sufficiently capacious to allow some hundred weights of the materials to be operated upon at once; and that I am of opinion that none of the means there directed can be profitably employed in this country during the present high price of salt, except by those whose manufactories may produce saline residuums, or whose locality of situation may give them peculiar advantages. The decomposition by potass, or by the oxides of lead, presents the fewest difficulties; but even these methods cannot be lucrative, unless at a time when potass and lead are at moderate prices.

† The natron lakes of Egypt annually produce a large quantity of mineral alkali. It probably arises from the decomposition of muriate of soda, by means of carbonate of lime, assisted by the heat of the climate. In summer the water of these lakes is evaporated by the sun, which leaves a bed of natron generally two feet thick; and this is broken up by wedges, and packed for the European markets.

Berthollet formed an *artificial* natron bed in one of the gardens of the National Institute, by the mixture of carbonate of lime, silex, and muriate of soda. After a time, a partial decomposition was effected, which was evident from the incrustation on the surface changing the colour of test paper.

and in the East Indies*; also in various parts of the world, united with other acids†.

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* Natron in large quantities is frequently sold at the English East India Company's public sales, and is brought by their vessels from China and other parts of the East.

† Soda exists native in borax, and in muriate of soda, which is our common culinary salt. Near Cordova in Spain there is said to be a mountain of this salt 500 feet high, and nearly three miles in circumference. The mine of Cracow in Poland is computed to hold salt enough to suffice the whole world for many thousands of years.

I copy the following extract from a letter received by a friend of mine from the Rev. Dr. Allison, dated Borden-Town, N. Jersey, Dec. 3, 1803:—"There has lately been discovered on the Missouri in Louisiana, a mountain of pure rock salt of the best quality, 80 miles long, 45 wide, and of an immense height. The surface is barely covered with earth, and there is not a tree or shrub growing on it. This is established as a fact, and some of the salt has been sent to Marietta on its way to Washington city. Various caves of saltpetre are found in its vicinity."

Soda has also been found in the proportion of 4 per cent. in common whinstone, and in volcanic lava. Edinburgh Trans. vol. v. As these specimens contained lime and muriatic acid, it is very probable that the soda was produced by the decomposition of muriate of soda by the agency of fire.

The *chrysolite* of Greenland, which is an insoluble fluate of alumine, is found to contain 36 per cent. of soda. Klaproth.

Soda is one of the substances found in the bile of animals. Whenever this alkali occurs native, it is always in a *mild* state; and as it cannot combine with oils to form soap, unless it be *caustic*, this causticity is given it for these manufactories by artificial means. It is worthy of remark, that Nature has furnished the bile with soda in a state of *causticity*, which gives it the property of combining with and saponifying the fat or oily

How have the fixed alkalies been distinguished from each other?

The one has been called the *vegetable*, and the other the *mineral* alkali‡.

What are the distinguishing properties of these two alkalies?

The fixed alkalies are very similar in their general properties§; but are easily distinguished

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substances taken into the stomach, and rendering them soluble in the other animal fluids. What account can be given of this deviation from the usual course of nature, but the important purpose which it serves in the animal œconomy?

‡ Potass was called the vegetable alkali, because it was supposed to exist only in vegetables, though it is now found in minerals, &c. Soda was called mineral alkali, because it exists in mineral salt.

Soda, as distinguished from potass, has been known but of late years. Even half a century ago, the salt which was artificially produced by the mixture of muriatic acid and potash was called "*re-generated marine salt*;" which shows that chemists had not then learnt to distinguish between potass and soda. Some of the properties of soda were known in times of remote antiquity. A Hebrew writer speaks of washing with natron. Jeremiah ii. 22.

§ When the fixed alkalies are in a state of purity, it is impossible by inspection to distinguish them from each other; and yet they form, by union with the *same* acid, salts very opposite in their saline properties and appearance. Thus the sulphuric acid and soda form a salt very soluble in water, which crystallizes in long separate six-sided prisms, effloresces in the air, and undergoes a watery fusion by the action of heat:

by the variety of salts which they form with the acids; and by potass being more deliquescent than soda.

Is there any chemical test by which you can distinguish these two alkalies?

There are many; but a solution of the ore of platina in nitro-muriatic acid will answer this purpose most completely*.

What are the chief uses of these alkalies?

The fixed alkalies have various uses in surgery

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whereas, the same acid and potass form a salt extremely difficult of solution, which crystallizes in hexahedral pyramids, or in short prisms, crossing each other at right angles, is not affected by the action of the air, and decrepitates in the fire.

The oxalic acid has been used as a test to distinguish the mineral from the vegetable alkali. With the latter it forms a very soluble salt, but with the former one of difficult solubility. Kirwan's Mineralogy, vol. ii. 7.

The acetous acid is one that may be employed, as it forms a *crystallized* salt with soda, and a *deliquescent* salt with potass. Potass may also be known from soda by supersaturating it with tartaric acid, with which it forms a salt very *insoluble* in water.

The alkalies, when combined with carbonic acid, form very *soluble* salts, while the earthy carbonates are nearly *insoluble* in water.

* If a little of any alkaline solution be poured into a solution of the ore of platina in nitro-muriatic acid, a yellow precipitate will be seen, if the alkaline solution contained potass; but if it contained only soda, no precipitate will occur. The peculiar

and medicine[†]; they are the bases of several salts; are employed much in the arts[‡]; and are also of great use to the analytical chemist[§].

How are the fixed alkalies employed in the arts?

The fixed alkalies are used in large quantities by the glass-maker[||], the dyer, the soap-maker, the colour-maker, and by various other manufacturers.

In a former chapter we noticed the use of fixed alkali in making glass:—can you tell the use of it to the dyer?

The alkalies are known to have the property

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advantage of this test consists in its ready application; whereas the old tests required time to ascertain the nature of the salts formed by their means.

[†] Fourcroy is of opinion that soda is more proper for medicinal purposes than potass, on account of its analogy with animal substances, which *always* contain it; while on the contrary no portion of potass is found in them.

[‡] The greatest consumption of the fixed alkalies in this country is in the manufacture of soap. They are also largely employed in bleaching, and in the manufacture of glass. Soda and potash are both used in washing, and for other domestic purposes; as they powerfully unite with all greasy substances, which they render soluble in water.

[§] See note, page 196.

[||] Soda has the property of fusing silex with more facility than potass; hence it is preferred by those glass-makers who have made trial of both these alkalies.

Soda is preferred to potash in most of the manufactures, because it is much less acrid, and does not attack or weaken the of altering the hue of most colours*: they are therefore employed with this view by the persons who are engaged in this trade.

Why are the alkalies employed in making soap?

An alkali is an essential ingredient in soap, as it is the only article capable of converting tallow or oil into a saponaceous substance, and enabling it to combine with water†.

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texture of piece (i. e. linen) goods, nor corrode and destroy utensils of wood, metal, &c. as potash does.

It is curious to observe that the alkalies combine with *transparent* olive oil and produce *opake* soap; and that they unite with *opake* sand to form *transparent* glass. How various are the properties that have been impressed upon those primary materials of the universe, that were intrusted to man for the promotion of his convenience and comfort!

[*] The fixed alkalies facilitate the solution of the colouring part of dye-goods, and generally render the colours darker.

[†] To make soap, it is necessary to employ a fixed alkali in a caustic state. In this country the business is usually conducted in the following manner: Spanish barilla or Scotch kelp is broken in pieces, or coarsely ground by a horse mill; and, when mixed with a sufficient quantity of quick-lime to absorb the carbonic acid, the whole is thrown into large wooden or iron vats, and covered with water. In large works, these vats are generally of cast iron, and sufficiently capacious to hold 3 or 4 tons of alkaline ashes. At a proper time, the water, impregnated with the caustic alkali, is let off into iron receivers below, and the vats are covered again with water, which, after standing a sufficient time, is let off as before. This liquor is called soap-boilers' ley. When a sufficient quantity of this is prepared, Russian or English tallow is put into a large iron boiler

Why are the fixed alkalies employed in making colours?

Many colours now manufactured in this country cannot be made without an alkali: thus, animal matters are incinerated with an alkali to form Prussian blue; a fixed alkali is also employed as a flux in the formation of mineral blue from cobalt; and in making other mineral colours.

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and melted with a portion of the above-mentioned alkaline ley. At first the tallow appears liquid like oil, but during its boiling it acquires by degrees consistence as it saponifies. When the alkali is uniformly combined with the tallow, the weak liquor is pumped from beneath the soap, and fresh leys are added in their stead. These are boiled as before, till the soap exhibits certain appearances well known to the manufacturer: it is then cooled down, and poured into deep wooden frames 15 inches wide and 45 inches long; where it remains till it has acquired a sufficient degree of solidity to be cut up for sale. It is the *alkali* which gives soap its detergent quality, and which renders it soluble in water. The tallow serves to moderate the sharpness of the alkali, and to prevent its injuring the hands of those who use it.

In making yellow soap, resin is used in the proportion of about 1 part to 3 or 4 parts of tallow. The resin makes the soap more detersive, and enables the manufacturer to sell it cheaper. Common fish oil, when its price permits, is also used in yellow soap.

Potass is the alkali used for soft soap, which is a distinct and separate trade in this country. A solution of this alkali in a caustic state is boiled with fish oil; and when the oil is sufficiently saponified, and a complete union of the materials formed, *What are the other uses of these alkalies?*

They are employed in making alum*, in bleaching, &c. &c.†

From whence is this country supplied with these alkalies?

The greatest part of the potass used in this country comes from America and Russia; but the kelp of our own coasts, and the barilla of Spain‡

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the *whole* is poured into small casks for sale; the water having combined with the oil as well as the alkali.

* Alum, which is a triple compound, cannot be perfect without the addition of a portion of potass or ammonia. For this purpose the British manufacturers generally use kelp (which contains a quantity of potass as well as soda), or black ash, which is an article made from the waste leys of the soap-boilers, and which, with other salts, generally contains a portion of muriate and sulphate of potass. Putrid urine is sometimes used, on account of the ammonia which it affords. For the process of alum-making see page 151.

† The design of using alkali in bleaching, is to loosen and carry off that particular substance in the cloth which occasions its brown colour, and which Dr. Home says is a kind of heavy oil. For further information consult Berthollet on dyeing, or Pajot des Charmes on bleaching.

‡ The soda of Spain is procured from the *salsola*, as has been noticed, and also from the *batis maritima*. The Sicily barilla which is imported into this country is chiefly made by the incineration of the *zostera maritima*. These plants must be endowed with some very peculiar organization for the decomposition of sea salt, superior to that of other marine vegetables; or why does not sea wrack (the *Fucus* of Linnæus) of the British shores, and other sea plants that are burnt for kelp,

and Sicily furnish us with most of our mineral alkali§.

Are these alkalies sold in a state of purity?

No: both potash and soda always contain a

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yield a proportionate quantity of soda. Whenever I have had occasion to lixiviate ordinary kelp, especially Irish kelp, I have not failed to observe that the neutral salts which precipitate from the solution, are not muriate of soda, as might have been expected, but *muriate of potass.* And this salt is so abundant, that I have often had many hundred weights of it from a single ton of kelp. From this circumstance, which formerly puzzled me not a little, I am now induced to believe that marine plants (excepting those that are cultivated for barilla) yield *potass* by incineration, and not *soda,* as has generally been imagined; and that the soda which occurs in kelp is produced by the operation of the potass on the sea-salt in the vegetable, or on that which is thrown into the mass by the burners to increase its weight: for a solution of carbonate of potass, poured into a boiling solution of sea-salt, always produces an immediate decomposition, the result of which is carbonate of soda and muriate of potass.

§ As we are indebted to foreign countries for most of our fixed alkalies, it would be a great national benefit if some ingenious chemist could discover an expeditious as well as œconomical mode of recovering the alkalies after they have been used for manufacturing or domestic purposes. The waste liquor might be evaporated; and if the residuum were calcined, the potass or soda would be recovered entire, and endowed with all the valuable properties which it originally possessed; as it is by nature indestructible. The desideratum is, how to divest it of its impurities, and how to calcine it at a small expense.

By examining "The Report of the Committee of the House of Commons appointed to inquire into the Laws relating to the Salt Duties," I find that from the 5th of Jan. 1800 to the 5th of quantity of carbonic acid* and water; and are often contaminated with various earths, and sometimes with a portion of sulphur†.

Have alkalies any peculiar affinity for sulphur?

Both potass and soda, as well as ammonia, have a strong affinity for sulphur; they combine by trituration or heat, and form *sulphuret* of alkali‡, formerly called *hepar sulphuris,* "liver of sulphur."

What is the nature of sulphuret of alkali?

Its colour is similar to that of the liver of ani-

Jan. 1801 the following quantities of alkali were imported into Great Britain:

	Cwt.	*Declared Value.*
Barilla	172,454	£.362,153 18 6
Pearlash	44,401	128,765 2 6
Potash	135,401	284,342 3 6

* The potash and soda of commerce contain nearly one 5th of their weight of carbonic acid, besides lime, silex, and other impurities.

† An ash which contains 20 per cent. of pure alkali is capable of taking up 15 parts of sulphur. Such ashes may be desulphurated by three processes: by calcining them in an open furnace exposed to a rapid blast of air; by saturating them with any vegetable acid; or by exposing them in a situation to imbibe carbonic acid. See a paper on this subject in the Irish Transactions for 1789.

‡ If equal parts of sulphur and pure potash are triturated together in a mortar, the sulphur will soon acquire a green colour, the temperature of the mixture will be raised, and a *sulphuret of potass* will be formed. Carbonate of potass or soda will answer for this purpose as well as the pure alkalies, if heat be employed.

mals; its taste is acrid and bitter; and it has the property of decomposing water§.

How are the alkalies of commerce purified for the use of the chemist or manufacturer?

Potash or soda is generally mixed with a portion of quick-lime to divest it of carbonic acid, and then lixiviated in proper vessels to obtain a solution of the caustic alkali, free from other impurities. When it is required *perfectly* pure for nice purposes, the alkali is dissolved in alcohol, and purified by a peculiar process||.

Are the fixed alkalies ever used in a state of combination with carbonic acid?

Carbonic acid gives potass and soda the pro-

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§ Sulphuret of potass or soda cannot exist but in a *dry* state, for it decomposes water when dissolved, and then sulphuretted hydrogen is produced.

|| The different methods which have been followed to purify the fixed alkalies, are detailed at length by Mr. John Thomson in his Notes on Fourcroy, vol. i. 373. Another method has been proposed by Lowitz, which may be seen in Nicholson's Journal, vol. i. 4.

Mr. Henry has suggested that the fixed alkalies may be purified from sulphate of potash, which generally contaminates them, by means of barytes. His method consists in rendering the alkali first perfectly caustic by quick-lime, and then adding to the clear solution a warm solution of pure barytic earth till the precipitation ceases. The barytes seizes the sulphuric acid, and leaves the alkali pure; which may, if required, be afterwards saturated with carbonic acid, in any of the common modes. During its restoration to a mild state, any barytes that may remain in excess is precipitated.

perty of crystallizing readily[*]: it also renders them mild[†], and fit for purposes in which caustic alkali would be improper[‡]; hence carbonate of potass is employed in medicine, and carbonate of soda for washing and other domestic uses.

What is the chemical name of volatile *alkali?*

It is called ammonia.

What are the properties of ammonia?

Ammonia is urinous and caustic; but it does not corrode animal substances like potass or soda. Its most simple state is that of gas[§]. In some

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[*] Carbonate of soda crystallizes very readily, and by proper management crystals of a large size may be procured. The potash of commerce is a sub-carbonate, which does not easily crystallize. However, if this be saturated with carbonic acid, by artificial means, crystals may readily be produced.

[†] Caustic soda is so corrosive that it will affect glass vessels in which it is kept, and render them brittle, like earthenware half burnt.

[‡] Carbonate of soda and carbonate of potass are of use in chemical laboratories as *re-agents*, being employed for purposes which could not be effected by the *caustic* alkalies. Thus the two fixed alkaline carbonates will precipitate barytes, strontian, lime, magnesia, manganese, and iron, from their solutions, by means of double affinity. But when these re-agents are employed to precipitate either of the three latter substances, if too much be used the precipitate will be *re-dissolved:* some nicety therefore is requisite in separating magnesia, manganese, and iron, from their solutions by this means.

[§] Ammoniacal gas is lighter than atmospheric air, in the proportion of 3 to 5: and, like it, is elastic and invisible; but it causes the death of animals that are obliged to breathe it.

of its combinations it is so extremely volatile, that it will bear no degree of heat without being dissipated‖.

As this alkali is a gaseous substance, how has it ever been applied in the arts?

Ammonia has an affinity for water¶, with which it readily combines, and forms *liquid* ammonia; in which state it is generally used*.

What is the composition of ammonia?

Ammonia is a compound of hydrogen and nitrogen, in the proportion of about two parts of the former, and eight of the latter†.

‖ Ammonia has another peculiar property, that of reducing the oxides of metals to a metallic state. Ammonia being composed of hydrogen and nitrogen, the hydrogen seizes the oxygen from the metal and forms water, while the nitrogen escapes in a gaseous form. Some metals are oxidized and dissolved by liquid ammonia.

¶ Water is incapable of dissolving either hydrogen or nitrogen, and yet when these are united in ammonia their nature is so changed that they become very soluble in water.

* It is owing to the levity of ammonia, that water becomes specifically lighter in proportion to the quantity of gas it contains. Next to hydrogen, ammonia is the lightest gas we are acquainted with. A cubic inch of it weighs only 0.27 parts of a grain, while atmospheric air weighs 0.46.

† One thousand parts of ammonia consist of 807 parts of nitrogen, and 193 parts of hydrogen. This is the result of experiment; we have therefore an accurate knowledge of the composition of this alkali.

By the following process ammonia may be formed, so as to become evident to the senses in a short time. Take some

Is this alkali capable of being decomposed?

Yes: ammonia may be decomposed by the electric spark. Oxygen gas will also decompose it by the assistance of heat—and nitrous acid and water will be the result*. If passed over red-hot charcoal, it will combine with part of the charcoal and form *prussic acid.*

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filings of tin or zinc, pour on them some moderately dilute nitrous acid. After a short time stir into the mixture some quick-lime, or caustic alkali, and a very strong pungent smell of ammonia will be produced. For the rationale of this experiment consult Dr. Rees's New Cyclopædia, article *Ammonia.* See also Higgins on Ammonia, and a curious paper by Dr. Milner in the Philosophical Trans. vol. lxxix. 300.

* Dr. Priestley was the first chemist who decomposed ammoniacal gas; but I believe Berthollet was the first who proved its composition by synthesis as well as analysis.

The decomposition of ammonia may be shown by the following experiment: Fill four-fifths of a long glass tube with strong oxygenized muriatic acid, and the remaining fifth with water strongly inpregnated with ammonia, and invert it in a saucer of water. When the tube is inverted, the ammonia, on account of its lightness, will pass through the oxygenized muriatic acid; but by its passing a strong effervescence is produced, and a decomposition ensues. When the effervescence has ceased, a portion of nitrogen gas will be found in the tube.

In this experiment the oxygen of the oxygenized muriatic acid combines with the hydrogen of the ammonia, and forms water; while the other component part of the ammonia, nitrogen, becomes disengaged in the form of gas. When the oxygenized muriatic acid is thus reduced to common muriatic acid, it unites with another part of the ammonia, and forms with it muriate of ammonia. I believe this experiment was first shown by Mr. Davy, at the Royal Institution.

How is ammonia procured?

All animal and vegetable substances will furnish ammonia when in a state of putrefaction †; this alkali is, however, generally procured in England by a dry distillation of bones, horns, and other animal substances ‡.

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† As the quantity of ammonia obtained from different substances corresponds with the quantity of nitrogen which they contain, and knowing that ammonia is one of the products of putrefaction, it has occurred to me that a manufacture of volatile alkali might be established with advantage on any part of the coast where herrings, pilchards, &c., arrive in such shoals as to be employed in manure for land. Besides, as fish bones contain more phosphoric acid than those of quadrupeds, the bones might be advantageously employed afterwards in the manufacture of phosphorus, &c.

‡ Ammonia is also found in mineral waters. According to Dr. Austin, ammonia is formed whenever iron rusts in water which has a free communication with the air. Phil. Trans. vol. lxxviii. 379.

For chemical experiments ammoniacal gas may be procured thus:—Mix one part of powdered sal ammoniac with two parts of powdered quick-lime in a retort, and apply the heat of a lamp, which will disengage the gas in abundance. On account of its affinity for water, this gas must be received over mercury.

Ammoniacal gas may be procured also by heating strong liquid ammonia, and collecting the gas as before.

Muriatic or acetic acid are the usual tests employed to discover the presence of ammonia. If either of these be held over any thing evolving ammonia, white fumes will appear, which are owing to the ammonia uniting with the acid, and forming a visible cloud, which is a true neutral salt in vapour.

What are the uses of ammonia?

In a liquid state ammonia has various uses in our manufactories*, and in medicine; it is a valuable re-agent to the chemist; and when combined with carbonic acid it takes a concrete form and a beautiful white colour, being then the article known in commerce by the name of *volatile salts*†.

Are there any other‡ *uses to which ammonia is applied?*

Ammonia is serviceable in dyeing, and in

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[*] Ammonia is of use in making archil, an article in great demand with dyers. A Florentine merchant about the year 1300, having accidentally observed that urine, which contains ammonia, imparted a very fine colour to a certain species of moss, he made experiments, and learned to prepare archil. Berthollet.

It is said that this alkali will give to *new* brandy all the qualities of that of the oldest date. The method consists in pouring five or six drops of aqua-ammonia into each bottle of brandy, and shaking it well, that it may combine with the acid, on which the taste and other qualities of the new liquor depend. Bib. Phys. Econ.

[†] When ammoniacal gas is passed into carbonic acid gas, the two gases become condensed, and a crystallization of carbonate of ammonia, in silky fibres or fine powder, takes place upon the internal surface of the vessel. This is a beautiful experiment; but it must be made over mercury, and not upon water, as water would absorb the ammoniacal gas.

[‡] It has lately been discovered that ammonia is useful in vegetation. See Dr. Darwin's Treatise on Agriculture and Gardening.

Muriate of ammonia has been found native in the neighbour-staining ivory; but its principal use is in making the muriate of ammonia, of which it is the basis.

How is ammonia formed into muriate of ammonia?

Muriate of ammonia is formed by combining ammonia with muriatic acid. It is known in commerce by the name of *sal-ammoniac*§.

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hood of volcanos, in some of the mountains of Tartary and Thibet, and in the waters of some lakes in Tuscany.

§ In this country liquid carbonate of ammonia is saturated with sulphuric acid, which forms sulphate of ammonia. This is decomposed by muriate of soda, from which result muriate of ammonia and sulphate of soda. The former is sublimed into cakes, and the latter crystallized for Glauber's salt.

In France a very considerable manufactory of sal-ammoniac was established a few years ago, on a plan very different to the usual practice. Leblanc de Franciade was the author of the process. He covered the brick floor of an oven heated to redness, with common salt, and poured thereon sulphuric acid. The muriatic acid gas which arose was conducted by a brick gutter into a large leaden chamber, where it met with a stream of ammoniacal gas, conducted thither from animal matters burning at the same time in three iron cylinders, placed in a furnace beside the former. These gases condensed by mixture, which was hastened by an eolipile heated by the same furnace. A full account of the process may be seen in Annales de Chimie, tom. xix. 61: it will, however, be better understood by examining a drawing of the apparatus in one of the volumes of the Journal de Physique; but not having at present access to that work, I cannot point out the volume in which it may be seen.

Sal-ammoniac is very profitably formed in France also by the

Muriate of ammonia being formed by two gaseous substances, how does it acquire solidity?

It may appear surprising that the union of two gases should produce a hard ponderous body; but this may be attributed to their loss of caloric. The bases of these gases having a greater affinity for each other than they have for caloric, they combine intimately whenever they come in contact; and the compound having less occasion for caloric than the separate ingredients, the caloric is given out, and a solid is produced*.

What are the uses of sal-ammoniac?

Sal-ammoniac is used in many of our manufactories, particularly by dyers, to give a brightness

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distillation of animal substances, and mixing the aqueous product with the mother-waters of the saline springs of La Meurth, Mount Blanc, &c., which contain muriate of lime and muriate of magnesia. By this mixture a double decomposition takes place; and the carbonates of lime and magnesia, being insoluble, precipitate, while the muriate of ammonia remains dissolved. The latter solution is then evaporated to dryness, and the salt sublimed for sale. See Annales de Chimie, tom. xx. 186.

* This mixture may be considered one of the most striking chemical combinations with which we are acquainted. Ammoniacal gas, and muriatic acid gas, are two of the most pungent and volatile substances known; they are so volatile and gaseous, that when in a state of purity neither of them can be condensed; and yet these gases are no sooner thrown together than they form a solid and inodorous substance, void of volatility, and of little taste.

to certain colours[†]; also by braziers, tinplate-workers, and others; and in medicine.

From whence was sal-ammoniac procured before it was made in this country?

Sal-ammoniac was formerly brought from Egypt sufficient for the supply of all Europe[‡]; but it is now made in various parts of Great Britain, particularly in Scotland, where it is formed by a peculiar process from soot.

Is ammonia capable of entering into any other combinations?

Yes: ammonia is capable of forming salts with most if not all of the acids[§].

[†] Sal-ammoniac is used also by dyers in what they call composition; it is employed to prevent the tin from precipitating. In tinning metals it is of use to cleanse the surfaces, and to prevent them from oxidizing by the heat which is given to them in the operation. This salt is employed also in the assay of metals, to discover the presence of iron.

[‡] Sal-ammoniac acquired its name from the Temple of Jupiter Ammon, it being first made in the neighbourhood of that temple. According to Pliny, there were large inns in the vicinity of this famous temple, where the pilgrims, who came to worship, lodged; and who usually travelled on camels. The proprietors of these stables had some contrivance for preserving and concentrating the urine of these beasts, and the salts which it produced were afterwards sublimed in glass vessels for sale. Pliny, lib. xxxi. c. 7.

[§] If ammoniacal gas be brought in contact with either of the acid gases, both lose their aëriform appearance, and a solid salt is produced. These salts are called *ammoniacal* salts. For an account of their properties consult the chapter on Salts.

Can you recapitulate the origin of the different alkalies?

Yes: the volatile alkali is procured from bones and other animal matters; the potass or vegetable alkali from the ashes of weeds and burnt wood; and the soda or mineral alkali from the ashes of some marine plants, also from sea-salt or muriate of soda*.

What is the natural inference from a consideration of the nature and production of the alkalies?

The reflection which naturally arises from a consideration of this subject, is, that the pristine

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* Soda may readily be procured from muriate of soda, common salt, by methods alluded to, page 184. As the act of parliament which imposes the tax upon salt, allows it to be used duty free for the separation of mineral alkali, to be consumed in making glass, a manufacture of soda has within these few years been established for that purpose at Wormbridge, near Wellington, in the county of Salop. I understand that at this place considerable quantities of martial pyrites are found intermixed with coal, and that the sulphuric acid obtained from this mineral is used in the decomposition. I have found by experiment, that if muriate of soda can be converted by any means to a *sulphate*, carbonaceous matter alone will finish the decomposition.

Near the towns of Wednesbury in Staffordshire, and Dudley in Worcestershire, there are masses of coal on fire, which have been burning for ages, owing probably to the decomposition of pyrites. In some cases, where the sulphurous vapour meets with aluminous earth, alum is formed upon the surface. An account of these subterranean fires may be seen in Plot's History of Staffordshire. We read also of a combustible ground of this kind, near Baku in Persia, where the followers of Zoroaster organization of matter, whereby the effete recrementitious parts of animals and vegetables are made capable of producing useful and powerful substances, evinces, that infinite Power and Wisdom, conjoined with consummate Beneficence, can effect the most *important* changes, by the most *unlikely* agents; and can convert to valuable purposes, substances which to us appear totally useless and inert †.

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perform their devotions. The carburetted hydrogen gas that arises from this ground is so abundant, that the priests have conducted it by hollow canes into one of their temples, where it burns continually, and is looked upon to be "the sacred flame of universal fire."

† This truth is beautifully illustrated by Dr. Darwin, in the following lines :—

"Organic forms with chemic changes strive,
Live but to die, and die but to revive;
Immortal matter braves the transient storm,
Mounts from the wreck, unchanging, but in form."

CHAP. VII.

OF ACIDS.

What is an acid[*] *?*

Most of the acids are substances which produce that sensation on the tongue which we call *sour*[†]; but some substances are classed with the acids which have not this characteristic—though they possess some of the other properties of acids.

What are the properties of acids ?

Acids[‡] change the blue juices of vegetables to

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[*] The acids differ from each other in their appearance and properties as much as any class of bodies we are acquainted with: it is therefore difficult to give a definition of an acid. In general they are liquids, but some of them take a solid, and others a gaseous form; some are mild, others corrosive; some are pungent and volatile, others are mixed and inodorous.

[†] According to Fourcroy, the stronger the attraction of oxygen for the acidifiable radical, the weaker is the taste of the acid: this shows that the corrosive quality of the stronger acids is owing to the *easy* separation of this principle, and its more or less rapid transmission to animal substances.

[‡] It is desirable as soon as possible to give the chemical student correct ideas of the properties of the acids and alkalies.

red; and combine with alkalies§, earths, or metallic oxides‖, so as to form those compounds called *salts.*

What is the origin of acids?

Most of the acids owe their origin to the combination of certain substances with oxygen¶, which has been called the acidifying principle.

To this end, let him be early instructed in the use of chemical tests. If he be accustomed to carry a few test papers in his pocket-book, it will be a very rational amusement to try the succulent vegetables which he will meet with in his walks, many of which will be found to contain acids of different kinds. The hope of making an important discovery will furnish an additional zest to this employment. Litmus paper is a good test for acids; and the same paper when reddened by vinegar, and afterwards dried, is a proper test for alkalies. Should litmus not be at hand, common writing paper rubbed over with the rind of the radish will answer every purpose.

§ All those substances which can saturate the alkalies, and cause their properties to disappear, ought to be classed among acids. This I understand is one of Mr. Hume's arguments to prove that *silex* ought not to be ranked among the *earths.*

‖ The acids have an affinity for the earths, alkalies, and metallic oxides; hence they are of great use as re-agents.

¶ The substances which are combined with oxygen to form acids are (in all the decomposable acids) *combustible* substances. Indeed several of the acids are the *product* of combustion: witness the sulphuric, the phosphoric, &c.

Four of the metals, and all the other simple combustibles, except hydrogen, are convertible into acids. All bodies, to which the properties of an acid have been ascribed, are either

How is it known that oxygen imparts acidity?

This is built upon analogy; for it is found that most of the acids contain oxygen, and that they lose their acidity exactly in proportion to the quantity of oxygen which is taken from them*.

Are there any other means of ascertaining this?

Yes: some acids may be decomposed and deprived of their oxygen, and others may be formed by a direct combination of oxygen with certain radicals †.

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combustibles, supporters of combustion, or may be produced by the process of combustion.

It is proper to remark that some of the acids are the productions of art, and are not known to exist in nature. This is the case with the mucous, the suberic, the oxygenized muriatic, &c.

[*] Many of the acids may be decomposed, and deprived of their oxygen, by combustible bodies. Any combustible body, that has a greater affinity for oxygen than oxygen has for the radical of the acid, will decompose that acid. Charcoal, when made red-hot, will in this way decompose sulphuric acid. By the disengaged oxygen of the acid the combustible burns; so that, in the language of the French chemists, the acid may be said to be *unburnt,* and brought back to the state of a combustible body.

[†] This is shown by the composition of sulphuric acid, which may be formed with very little trouble in the following manner: Have ready a small cup with a little powdered sulphur in it, a jar of oxygen gas containing some water, and a red-hot iron wire. Place the cup to swim on the water, then set fire to the sulphur, with the wire, and instantly cover the jar. The sulphur will burn with great rapidity, and will be entirely converted into sulphuric acid, which may be concentrated by

Do the same radicals always combine with an equal portion of oxygen?

No: some acidifiable radicals combine with different proportions of oxygen, producing different states of acidity ‡.

How do chemists distinguish this difference?

When two acids have the same radical, but contain different quantities of oxygen, they are distinguished by their termination §. The name of that which contains most oxygen ends in ic,

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evaporating the superfluous water. In this process the sulphur and oxygen unite, and the heat and light, which are unnecessary in the new compound, are evolved, and become sensible to our feelings; and the result is a new substance widely different from either, viz. sulphuric acid. The use of the water is to absorb the gas, and render it liquid. If oxygen gas be not at hand, the experiment will answer in common air, if the sulphur be mixed with $\frac{1}{8}$th of its weight of dried nitre.

‡ The first portion of oxygen converts some bodies into oxides; the second, into that class of acids of which the specific names drawn from their particular bases terminate in *ous*, as the sulphurous acid; the third degree of oxygenizement changes some of these into that division of acids which are distinguished by the termination in *ic*, as the sulphuric acid; and lastly, we can express a fourth degree of oxygenizement by adding the word *oxygenized* to the name of the acid, as oxygenized muriatic acid.

§ It is necessary to remark that this mode of distinguishing the doses of oxygen in acids is restricted to that class of acids which is formed by the combination of one simple combustible with oxygen, and does not apply to those acids which are formed with compound radicals and oxygen.

the other in ous. Thus we say *sulphuric* acid, and *sulphurous* acid; *phosphoric* acid, and *phosphorous* acid.

Have acids ever any other degree of acidity?

We have attempted to supersaturate several of the acids with oxygen, but have succeeded only in one instance *.

Which of the acids has been thus supersaturated with oxygen?

The muriatic acid, forming with two different portions of oxygen, two other distinct acids, called oxygenized muriatic acid †, and hyper-oxygenized muriatic acid ‡.

What substances are capable of being acidified by oxygen?

The mineral, the vegetable, and the animal kingdoms, all furnish bases or radicals, which become acid by their union with oxygen §.

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[*] The world is indebted to Scheele for the discovery of this combination of oxygen with an acid. He named it the dephlogisticated marine acid; supposing that it was formed by depriving common muriatic acid of its phlogiston.

[†] Though this compound has hitherto been classed among acids by chemists, it possesses few properties which characterize that class of bodies. Its taste is not acid, but astringent; it does not convert vegetable blues to red, but destroys them, and combines very sparingly with water.

[‡] For an account of the properties of this acid see the chapter of Salts, article *hyper-oxygenized muriates.*

[§] The mineral acids are generally formed with a peculiar base and oxygen; the vegetable acids, with carbon, hydrogen, *Do all the acids owe their acidity to the presence of oxygen?*

The greater number of the acids are evidently indebted to oxygen for their acidity, but there are substances that possess acid properties which contain no oxygen ‖. There are also three acids whose composition is unknown ¶.

How are the acids classed by chemists?

The acids were formerly divided into three classes, viz. the mineral, the vegetable, and the animal acids; but the more useful and scientific way of dividing the acids is into two classes only.

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and oxygen; while the animal acids are composed of the same substances united with nitrogen.

Some of the mineral acids are decomposable by charcoal heated to redness. Some of the vegetable acids are also decomposed, and reduced into water and carbonic acid, by leaving them in an exposed situation to the action of their own principles: others may be changed into different acids, by imparting or abstracting a portion of oxygen.

The animal acids are of all others the most liable to decomposition. In an elevated temperature the carbon and oxygen unite to form carbonic acid, and the hydrogen and nitrogen produce volatile alkali.

‖ Sulphuretted hydrogen has all the properties of an acid without oxygen. And it has not yet been proved that prussic acid contains any oxygen.

¶ Those acids, whose bases are still unknown, are the muriatic, the fluoric, and the boracic.

How are the acids now divided * ?

The undecomposable acids, and the acids which are formed with two principles, are comprised in the first class; while those acids which are formed with more than two principles compose the second class †.

Can you enumerate the acids of the first class?

The sulphuric and sulphurous acids; the muriatic and oxygenized muriatic acids; the nitric, the carbonic, the phosphoric and phosphorous, the fluoric, the boracic, the arsenic, the tungstic, the molybdic, and the chromic acids.

Enumerate the acids of the second class.

The acetic, the oxalic, the tartaric, the citric,

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* Those acids of the first class, which are formed with two principles only, are composed of oxygen and some other substance which is called their radical. The acids of the second class are composed chiefly of oxygen, hydrogen, and carbon; though some of them contain nitrogen, as mentioned in a former note.

† Fourcroy in his last work, entitled "Philosophie Chimique," divides the acids into four classes: 1st, those with known radicals; 2d, unknown ditto; 3d, single ditto; 4th, compound ditto: but I conceive that the above division is better calculated for an elementary treatise.

In the first class we have also the hyperoxygenized muriatic acid; but as this acid has never been exhibited in a separate state, its properties are very little known. In the second class we have also the mellitic acid; but as this acid has been found only in a very rare mineral, its properties are likewise very little known.

the malic, the lactic, the gallic, the mucous, the benzoic, the succinic, the camphoric, the suberic, the laccic, the prussic, the sebacic, the uric, and the amniotic acids.

What is the SULPHURIC *acid?*

The sulphuric acid is a combination of sulphur and oxygen ‡. It is commonly called oil of vitriol §.

How is the sulphuric acid obtained?

Sulphuric acid is procured by burning sulphur in contact with oxygen; by which process the sulphur combines with the oxygen, and becomes acidified ||.

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‡ One hundred parts of pure solid sulphuric acid have been said to consist of 72 parts of sulphur and 28 of oxygen; but, according to some late experiments of Mr. Chenevix, it is composed of 61.5 sulphur and 38.5 oxygen.

§ This acid was formerly drawn from green vitriol (sulphate of iron): hence its name. It has been remarked that the old name *oil* conveys an erroneous idea of the composition of this acid, and that on this account it ought to be entirely dropped. Oil is a compound of carbon and hydrogen; but sulphuric acid contains neither of these substances.

|| The pupil may be satisfied that sulphuric acid is really produced by the combustion of sulphur, by burning a little sulphur in a glass jar of oxygen gas inverted over water, as directed, page 208. He may see that sulphuric acid has actually been formed by adding a few drops of a solution of muriate of barytes to the water, from which it will precipitate the barytes.

If sulphuric acid is nothing more than sulphur and oxygen, what is it that occasions its fluidity?

Sulphuric acid, at the instant of its formation, is in a gaseous state; therefore the manufacturers find it necessary to condense this gas by means of water. Hence the sulphuric acid of commerce is always in a fluid state *.

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* In the large manufactories for making sulphuric acid (called oil of vitriol works) the sulphur is mixed with $\frac{1}{8}$th of its weight of dried nitre, and burnt in very large leaden chambers, according to the plan of Dr. Roebuck, to whom we are indebted for this process. The design in using the nitre, is to give a larger quantity of pure oxygen gas than could be afforded by confined atmospheric air alone. The floor of the chamber is covered with water, that the sulphuric acid gas may be condensed as it is formed. An indefinite quantity of water is poured into the chamber; and when the manufacturer finds that it is become sufficiently acid, this weak acid is drawn off, and concentrated by boiling. It is then removed to glass retorts, where it receives a greater heat to drive off a further portion of the water. It is considered fit for sale when it is brought to the specific gravity of about 1.845. By keeping it in the retorts for a long time, and in a temperature somewhat lower, it may be concentrated to the specific gravity of 2.000; but it is never brought to this gravity for general sale. A new theory has lately been given of the formation of sulphuric acid. See Nicholson's Journal for May last.

It is possible to render sulphuric acid perfectly transparent without retorting; but such acid is always contaminated with sulphurous acid and nitrous gas. The heat which it acquires in the retorts separates these acids, which go off in combination with the water in a gaseous state.

What are the properties † *of sulphuric acid?*

The sulphuric is a very ponderous ‡ corrosive acid, destitute of colour and smell, and has a very strong acid taste. It has a great attraction for water §, and, when combined with the alkalies, the earths, or the metallic oxides, forms with them those salts called *sulphates* ‖.

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† When sulphur is combined with a smaller portion of oxygen it forms a volatile acid of a penetrating smell, called *sulphurous* acid; a larger portion of oxygen gives what we call *sulphuric* acid, which on the contrary is very ponderous and destitute of smell.

‡ Sulphuric acid will sometimes freeze, and endanger the bursting of the carboys in which it is contained. Whenever this happens, it is a proof that the manufacturer has not sufficiently concentrated it. If it be brought only to the specific gravity of about 1.780, it will freeze much sooner than water. Mr. Keir first pointed this out in the Philosophical Transactions for 1787.

§ Sulphuric acid has a great affinity to water; they combine so intimately that the new compound gives out a large portion of caloric, and becomes very much condensed. Four pounds of this acid mixed with one pound of water will raise the thermometer to 300°.

The sulphuric acid of commerce is never perfectly pure—it always contains a portion of sulphate of lead and sulphate of potass. The former comes from a partial dissolution of the lead of the chamber in which it is made, and the latter from the nitre which is always used in the process.

Concentrated sulphuric acid does not act upon lead unless by the assistance of heat. It acts slowly upon iron; but if diluted it dissolves iron with great rapidity. Excepting iron and zinc, most of the metals are insoluble in diluted sulphuric acid.

‖ Sulphuric acid is a good test for barytes; a single drop

What is the SULPHUROUS *acid?*

The sulphurous acid, like the sulphuric, is a combination of sulphur and oxygen, but with less oxygen, or, we may say, with more sulphur, than the latter*.

What are the properties of sulphurous acid?

Sulphurous acid in the gaseous state is invisible like air, but of a strong suffocating smell †. It

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poured into any solution of this earth instantly causes a white precipitate. It is also a good test for lead. I know, however, of *one* case where this acid cannot detect the presence of barytes, and that is when sulphuric acid is contaminated with this earth. Mr. Hume has shown, that sulphate of barytes is completely soluble in sulphuric acid. Phil. Mag. vol. xiv. 357.

[*] Sulphurous acid gas is produced by the *slow* combustion of sulphur. If this gas be received in water, the gas combines with it, and sulphurous acid will be the result. Water at 40° absorbs one third of its weight of sulphurous acid gas.

Sulphurous acid gas may be procured by the following process: Put into a glass retort two parts of sulphuric acid and one of mercury, and apply the heat of a lamp; the mixture effervesces, and a gas issues from the beak of the retort, which may be received in glass jars filled with mercury and standing in a mercurial trough. In this process the mercury combines with part of the oxygen of the sulphuric acid; and the sulphuric acid, having lost a certain portion of its oxygen, is converted into *sulphurous* acid.

Any combustible substance will decompose sulphuric acid, by combining with a portion of its oxygen, and sulphurous gas will be evolved.

[†] This gas is very abundant in the environs of volcanos. It was the vapour of sulphurous acid which suffocated Pliny the naturalist, in that eruption of Vesuvius by which Herculaneum

is readily absorbed by water, and then forms liquid sulphurous acid. It is capable of uniting with various bases, and forms the salts called *sulphites.*

What is the MURIATIC *acid?*

The muriatic is a peculiar acid obtained from sea-salt‡. It has been supposed that it acquires

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was swallowed up in the year of Christ 79. Anxious to observe the effects of the eruption, he staid in the house of a friend too long, and paid for his temerity with his life.

Sulphurous acid gas is composed of 68 parts sulphur and 32 parts oxygen. Its weight is more than double that of atmospheric air.

This gas has been prescribed by physicians in affections of the lungs. The liquid acid is administered in asthmas.

Sulphurous acid gas is used by manufacturers in bleaching silk. A slow combustion of sulphur is promoted in a close chamber, and the goods are exposed to the gas as it is produced. The same process is employed to alter the hue of different colours. Thus, silks which are dyed by archil of a dark lilac are brought to a beautiful flesh-colour by exposure to the fumes of this gas. Flesh-coloured silk stockings are coloured in this way.

Sulphurous acid possesses very slight acid properties. Instead of changing vegetable blues to a red, it invariably renders them white. Thus, if a red rose be held in the fumes of a brimstone match, the colour will soon begin to change, and at length the flower will have become white. By the same process, fruit-stains or iron-moulds may be removed from linen or cotton cloths, if the spots be previously moistened with water.

‡ Glauber was the first who procured muriatic acid from

its acid properties from oxygen; but however this be, the radical or base of this acid is still unknown *.

What method is made use of to collect and preserve the muriatic acid?

Muriatic acid is distilled from sea-salt by means of sulphuric acid, and collected in appropriate receivers, where it is condensed in water, for which it has a powerful affinity †.

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sea-salt by means of sulphuric acid; but the directions given by him in the first part of his Treatise on Philosophical Furnaces, 1651, quarto, page 9, are truly ludicrous and absurd.

This acid was known only in a liquid state till Dr. Priestley taught us how to procure it perfectly pure in a gaseous form.

Mr. Chenevix has proposed a new nomenclature for this acid, and its combinations with oxygen:—he proposes to say

Muriatic radical	instead of	Muriatic acid,
Muriatous acid		Oxygenized muriatic acid,
Muriatic acid		Hyperoxygenized muriatic acid.

Phil. Trans. vol. xcii. 126.

* Berthollet has published a memoir, in which he endeavours to prove that this acid is composed of nitrogen, hydrogen and oxygen. He says that if iron filings moistened with water be exposed for some days to the air, they will exhibit evident traces of the presence of muriatic acid.

Dr. Lambe, an ingenious physician, late of Warwick but now of this city, is of opinion that sulphuretted hydrogen is the base of this acid. See Manchester Mem. vol. v.

† Muriatic acid is disengaged from muriate of soda in the state of gas, by a process similar to that for drawing the nitric acid. it preserves its gaseous state even in the coldest temperature, unless it come in contact with water; and if thrown upon ice

What are the properties of muriatic acid?

This acid in the gaseous ‡ state is invisible like air; has a pungent suffocating smell; and is not decomposable by art §. With water it forms the liquid muriatic acid, which preserves

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it melts it in an instant. It is nearly double the spec. grav. of atmospheric air.

Liquid muriatic acid, or water saturated with this gas, is about the spec. grav. 1.196. The muriatic acid of commerce varies from about 1.120 to about 1.164.

Bergman says, that 100 parts of muriate of soda contain 52 of muriatic acid and 6 of water. That this statement is erroneous, any one may satisfy himself of by experiment. I have frequently tried it in the large way, and could never procure more than 44 parts of acid and water from 100 parts of dried muriate of soda. In forming muriatic acid, every gallon of water employed, absorbs, according to Murray, 360 gallons of muriatic acid gas. This accounts for the great heat which is evolved during the operation.

‡ Muriatic acid gas may be obtained for chemical experiments, by pouring one part of sulphuric acid upon two parts of dry muriate of soda in a tubulated retort, and collecting the gas, as it becomes disengaged, over mercury in a pneumatic apparatus. This gas may also be collected by heating the muriatic acid of commerce in a glass retort.

Retorts are not always of glass; they are sometimes made of stone-ware, or iron. They are of various sizes, from eight ounces to eight or nine gallons. The best stone-ware retorts are made by Messrs. Wedgwood and Byerley. Glass ones may be had at the large glass warehouses in London, and elsewhere. A great variety of all kinds for experiments are sold by Messrs. Knights, in Foster-lane, Cheapside.

§ Sulphuric, phosphoric, nitric, and other acids may be de-the smell of the gas, and gives out white fumes when exposed to the atmosphere. This acid is much employed in the arts*, and in chemical laboratories. With various bases it forms the salts called *muriates* †.

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composed by charcoal: muriatic acid is unalterable by any of the combustibles with which we are acquainted.

Muriatic acid will decompose the carbonates, the phosphates, and most other salts; but it is itself generally expelled in its turn by the sulphuric acid.

* Muriatic acid is the best test for silver. If a single drop be poured into any solution containing this metal, a copious precipitate will immediately follow, owing to the affinity of this acid for silver, and the insolubility of muriate of silver.

† Muriatic acid attacks oxide of iron with more rapidity than the sulphuric. It dissolves tin and lead. At a boiling heat it oxidizes copper.

Muriatic acid removes the stains of common ink, but it does not affect printers-ink. It is therefore recommended for cleaning old books and prints. Half an ounce of red-lead being added to three ounces of common muriatic acid, will render it fit for this use. Where writings have been effaced for fraudulent purposes with this acid, sulphuret of ammonia and prussiate of potash will revive the writing, and discover the artifice. Very old writing may be revived in this way. If indigo and oxide of manganese be added to common ink, it will prevent its being effaced by oxygenized muriatic acid.

The citric acid is proper for removing ink stains from linen, but they are best removed when recent. If they remain long on the cloth, the iron of the ink acquires that degree of oxidizement which renders it insoluble in acids. When ink stains are thus become what are called *iron-moulds*, they may be removed by oxalic acid, or by first washing them with a solution of sulphuret of potash to absorb the oxygen, and then applying the acid of lemon as usual.

What is the OXYGENIZED MURIATIC *acid?*

The oxygenized muriatic acid is formed with muriatic acid and oxygen‡. It is known in the gaseous state, and in combination with water: in the latter form it is commonly used in the arts.

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‡ Oxygenized muriatic acid is composed of 84 parts muriatic acid and 16 oxygen. The hyperoxygenized acid is formed with 35 parts acid and 65 oxygen. Mr. Chenevix. Phil. Trans. 1802.

Muriatic acid has a great affinity for oxygen. When fully oxygenized it seems to have lost several of its acid properties, as it is incapable even of expelling carbonic acid from alkalies or lime, except in its nascent state. If oxygenized muriatic acid be exposed to light, the light combines with part of the oxygen, and the oxygenized muriatic acid is then converted into common muriatic acid.

The effect of giving a dose of oxygen to this acid is quite the reverse of the acid of sulphur, it being rendered more volatile thereby, and of a very penetrating smell; whereas the addition of oxygen to sulphurous acid gives it more density, and renders it quite inodorous. The combination of oxygen gives a greenish yellow colour to this gas. Common muriatic acid gas is invisible.

This gas may be obtained for chemical experiments by the following method: Put into a retort a little black oxide of manganese in powder; and pour upon this double its weight of strong muriatic acid, connect the retort with the pneumatic trough, and receive the gas over water. When the ascension of the gas slackens, apply the heat of a lamp, and it will be disengaged in abundance.

If a small quantity of liquid oxygenized muriatic acid be wanted for experiment, it may readily be formed by dissolving

What are the properties of oxygenized muriatic acid?

The oxygenized muriatic acid gas is so suffocating, that it cannot be breathed without great injury*; yet it will support combustion. This acid discharges vegetable colours†; it ox-

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a few grains of oxygenized muriate of potass, and adding the solution to an ounce of common muriatic acid.

The variolous poison will not take effect when mixed with oxygenized muriatic acid. Hence Fourcroy imagines that this acid would prevent the effects of hydrophobia. See his paper on oxygen in Annales de Chimie.

Accounts have been received from Spain, that in the midst of the dreadful contagion which reigned in that country, the inhabitants of those houses where fumigations of oxygenized muriatic acid were used, had no attacks of the sickness, and enjoyed the best health.

* The death of the ingenious and indefatigable Pelletier was occasioned by his attempting to respire this gas. A consumption was the consequence, which in a short time proved fatal.

† Acids change blue vegetable colours to red; this makes them white, by imparting its oxygen, and is itself changed thereby to common muriatic acid.

The great use of oxygenized muriatic acid is in bleaching. The colouring principles of vegetables have a great affinity for oxygen; they therefore absorb oxygen from this acid, and after this absorption become soluble in alkalies. On this principle the modern practice of bleaching is founded. The manufacturer might derive considerable advantage from the perusal of Mr. Rupp's paper on the use of this acid, in the fifth volume of the Memoirs of the Manchester Society. See also Charmes on Bleaching, 8vo.: Robinsons, 1799. C. Potel of the Academy of Dijon has shown that the fears of those who suppose idizes all the metals[‡], and is the only acid that will dissolve gold and platina[§]. With various bases it forms salts, called hyperoxygenized muriates.

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this process *burns* the cloth are groundless; and that, if the operation be performed by a careful workman, it improves the texture of the cloth instead of injuring it. Phil. Mag. vol. xiv.

[‡] It oxidizes all metals without the assistance of heat. Metals beaten into thin leaves, or reduced to powder, inflame when thrown into a vessel filled with this gas, provided the temperature be not lower than about 70°, and present a kind of shower of fire. The following is a pleasing and instructive example:

Prepare a jar of oxygenized muriatic gas, and suspend in it a piece of Dutch metal, or copper-foil: it will inflame immediately, and the combustion will continue till the whole is consumed, affording a very striking spectacle. As the metal combines with the oxygen, the acid dissolves it, and thereby acquires a green colour. This will subside in the jar, and form a substance exactly similar to the native muriate of copper brought from Peru. The experiment affords an example of the oxidizement of metals, and of the affinity which acids have for metallic oxides.

[§] Nitro-muriatic acid will dissolve gold; but this is owing to the muriatic acid having acquired oxygen from the nitric, sufficient to convert it to oxygenized muriatic acid.

Mr. Humboldt has found that seeds which do not commonly germinate in our climates, or in our hot-houses, and which of course we cannot raise for our gardens, or hope to naturalize in our fields, become capable of germinating when immersed for some days in a weak oxygenized muriatic acid. This interesting discovery has already been turned to advantage in several botanic gardens.

What is NITRIC *acid?*

Nitric acid is one of the constituent parts of nitre, or salt-petre[*]. It is a composition of oxygen and nitrogen[†], in the proportion of about 25 parts by weight of the latter, to about 75 of the former[‡].

How is nitric acid obtained?

Nitric acid is obtained by distilling two parts of nitre and one part of sulphuric acid in a glass

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[*] Nitric acid was known to Raymond Lully in the thirteenth century; but it was Mr. Cavendish who discovered its component parts, in the year 1785. See his paper in the Philosophical Transactions for that year.

[†] If a proper mixture of these gases be made in a glass tube, and a number of electric explosions passed through the mixture, the gases will unite, and *nitric acid* will be the product. As nitric acid is formed of the same substances with atmospheric air, we have no difficulty in accounting for the natural production of saltpetre.

[‡] These proportions were ascertained by Mr. Davy.

It is curious that the substances which compose atmospheric air, so necessary to our existence, should, in different proportions, produce also one of the most corrosive acids.

22 parts of oxygen, with } form asmospheric air.
78 —— of nitrogen, }
——100

75 parts of oxygen, with } form nitrous acid, or aqua-fortis.
25 —— of nitrogen, }
——100

Should the evidence, already adduced, not be sufficient to convince us of the *infinite* comprehension of the Divine mind, such facts as these are surely irresistible. None but Deity could have had a conception how such *different* substances could have been produced from the *same* principles.

retort, and collecting the gas in proper receivers§. This acid, which at first contains nitrous gas, is in a great measure deprived of it, and rendered transparent and colourless by the application of heat in a subsequent process.

What are the properties of nitric acid?

Nitric acid is clear and colourless, like water; its smell is acrid, its taste exceedingly acid, and its action on animal substances very corrosive. It has the property of permanently staining the skin yellow. It has a great affinity for water‖; is capable of oxidizing most of the metals¶, and with various bases forms the salts called *nitrates.*

What constitutes the acid of commerce, called NITROUS *acid?*

Nitrous acid is nothing more than nitric acid*

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§ The manufactories of this acid are commonly called aqua-fortis works. The acid is drawn of different strengths, from 1.125 to 1.460, according to the purposes for which it is designed. It is used in dyeing, in refining gold, in medicine, &c. &c. From the slight union of its constituent parts, this acid is very prone to decomposition; hence the violence of its action in many cases.

‖ It appears very singular that nitrate of bàrytes, which is so soluble in water, is perfectly *insoluble* in nitric acid. This was first noticed by Mr. Hume. See his observations on barytes, in the 14th vol. of the Philosophical Magazine.

¶ If nitric acid be poured on iron filings, the acid will in part be decomposed; its oxygen will render the metal soluble, and the nitrous gas will be thrown out in copious red fumes.

* It was formerly supposed that this acid differs from *nitric*

impregnated with variable portions of nitrous gas*.

What are the properties of nitrous acid?

Nitrous acid is very similar to *nitric* acid in its properties†; but its colour varies according to the proportions of nitrous gas which it has absorbed, and the water which it contains‡.

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acid in this—that it contains less oxygen: hence it was called, agreeably to the new nomenclature, *nitrous* acid; but it is now found that this is not the case: it is merely nitric acid coloured by nitrous gas, or nitric oxide. For a further account of this gas, see chap. xi.

* Dr. Priestley having separated nitrous gas from nitric acid, by means of iron, received the gas under an inverted vessel filled with water, and found it a transparent *colourless* gas, resembling air; whence it appears that it is red or coloured, only when combined with atmospheric air. To Dr. Priestley we owe the discovery, that nitrous gas is converted into nitrous acid by its union with oxygen and water. See Priestley on Air.

On the principle that oxygen gas is necessary to convert nitrous gas to nitrous acid, Dr. Priestley invented his eudiometer, to discover the degree of purity of atmospheric air.

† Nitrous acid is generally used for purposes of manufacture and experiment. The *nitric* acid is principally employed in medicine. Two parts of either nitrous or nitric acid, and one of muriatic acid, form aqua-regia, or nitro-muriatic acid, the true solvent of gold. It is curious that aqua regia has less specific gravity than either of the acids from which it is composed.

‡ The changes which take place on the addition of water to strong nitrous acid exhibit very curious phænomena. Different portions change its colour to a blue, a green, a yellow, &c. while the vapours which rise from it preserve their original flame-coloured red.

What is CARBONIC *acid?*

Carbonic acid[§] is a combination of carbon and oxygen. It was formerly called fixed air, on account of its being found in chalk, limestone[||], magnesia, &c.

What are the properties of carbonic acid?

Carbonic acid is invisible when in the state of gas, and unfit for combustion[¶], or respiration[*]. Water, by pressure, may be made to absorb three times its bulk of this gas; by which it

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[§] It is to Dr. Black we owe the discovery of carbonic acid gas. Mr. Keir was the first who suspected it to be an acid; and Dr. Priestley afterwards announced that this gas entered into the composition of atmospheric air.

[||] Carbonic acid is composed of 18 parts carbon and 82 oxygen; which has been ascertained by analysis as well as synthesis. Mr. Tennant was the first who decomposed this acid. This he effected by the following means: He burnt phosphorus in a close vessel, in which was a portion of carbonate of soda. The phosphorus absorbed the oxygen from the carbonic acid, and the carbon was separated in the form of a black powder.

[¶] If this gas be poured from a wide-mouthed jar upon a lighted candle, it will be as effectually extinguished as by water. Its superior gravity to atmospheric air, and its unfitness for supporting combustion, may also be shown by pouring a common glass full of this gas into another tall glass, containing a short taper burning within it.

[*] Fourcroy says, this gas, largely diluted with atmospheric air, may be inhaled without danger, by patients who have symptoms of ulceration, or inflammation of the lungs; and that it will either cure these complaints, or retard their destructive effects.

acquires an agreeable acidulous taste*. Carbonic acid enters into combination with the alkalies, with earths, and metallic oxides; and forms with them those salts called *carbonates*†.

What is PHOSPHORIC *acid?*

Phosphoric acid is a compound of oxygen and a peculiar substance called phosphorus‡.

How is phosphoric acid procured?

Formerly phosphoric acid was procured only by burning the phosphorus obtained from urine in oxygen gas; but, since it is known that this acid is a component part of animal bones§, we now procure it at a much cheaper rate.

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* Carbonic acid gas is found in abundance in many natural waters. Those of Pyrmont, Spa, and Seltzer, are instances; the last particularly, is highly impregnated with this acid. These waters are so pleasant and salutary, that various imitations of them, made in this country, are sold under the names of single and double soda water. They are manufactured by several houses in London, equal in every respect to the natural waters imported from the continent.

† The earthy carbonates are insoluble in water. Hence, breathing into a phial of lime-water renders it turbid. Owing to this, lime-water is a good test for the presence of carbonic acid.

‡ During a great part of the last century, phosphoric acid was supposed to be a modification of the muriatic acid. This error originated with Stahl. In 1743, Margraff distinguished it from all other acids; and in 1772, Scheele discovered that it was a component part of animal bones.

§ When animal bones are divested of their oil and jelly, the earth which remains is chiefly lime, united with phosphoric

What are the properties of phosphoric acid?

Phosphoric acid, deprived of water, is solid, and transparent||; when liquid, it has a thick oily appearance, is of considerable gravity, and

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acid. It is worthy of notice, that phosphate of lime is found in abundance also in milk. This seems to indicate, as Fourcroy beautifully remarks, " that Nature thought fit to place in the first nourishment of animals a quantity of osseous matter, with a view to the necessary celerity of the formation and growth of the bones in the earliest stage of their lives." This fact is probably unknown to some who study natural history, and is one of the numerous instances of the beneficence of the Creator, exemplified by the science of chemistry. The more we know of the minutiæ of matter, and of the laws by which it is governed, the greater occasion shall we have to admire the excellence of contrivance and the benevolence of intention of the Omnipotent Artificer. Let the advocates for chance consider the aforesaid fact, and say, if they can, that phosphate of lime is found in animal milk, in consequence of *fatality*, and that it occurs by *accident* where it performs so important an office in the animal œconomy.

It is a remarkable fact, that the nearer the female approaches to the period of parturition the more is the milk charged with this calcareous phosphate; and that it is not till the digestive organs of the infant are sufficiently strengthened to answer the purposes and the work of animalization, that this earthy salt disappears from the milk of the mother. See Nicholson's Journal, 4to. vol. i. 205.

|| Pure phosphoric acid obtained, without the addition of water, by burning phosphorus in oxygen gas, has the form of white, snowy, light flocks, of a very strong acid taste. By exposure to the air it attracts humidity, and becomes a *fluid* acid. Forty ounces of phosphorus will produce more than 100 ounces of dry acid.

very acid to the taste*. It forms, by its union with earthy, alkaline, and metallic bases, that variety of salts which we call phosphates.

What is the PHOSPHOROUS *acid?*

This acid contains a smaller proportion of oxygen than the phosphoric acid. It is procured by the *slow* combustion of phosphorus†; for when phosphorus is heated it burns *rapidly*, and the product is phosphoric acid.

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[*] Phosphoric acid may be concentrated till it is of greater specific gravity than sulphuric acid; but though the taste is very acrid, it does not possess a causticity sufficient to burn organic substances, like the latter, whose oxygen is retained with less obstinacy.

If phosphoric acid be exposed to heat, it gradually becomes thick and glutinous; and if the heat be continued it acquires more consistence, and at last melts into a solid transparent glass. This phosphoric glass must be preserved from the action of the atmosphere, or it will be gradually dissolved again into liquid phosphoric acid. If the phosphoric acid has been fused in an *earthen* crucible, it will not be deliquescent nor soluble in water.

This acid has been prescribed by some physicians as an antiseptic, cooling, and solvent medicine, and as an external application in osseous tumours.

[†] Phosphorous acid is generally prepared by exposing sticks of phosphorus to the action of atmospheric air, in a glass funnel, and receiving the acid, as it forms, in a bottle placed underneath. Two or three pieces of broken glass placed in the neck of the funnel to support the phosphorus, and a small quantity of distilled water put into the receiving bottle, complete this simple apparatus. The pieces of phosphorus should be placed so as not to touch each other.

What are the properties of phosphorous acid?

Phosphorous acid is a dense, viscid liquid, with an acid taste, and emits the smell of garlic when heated. Like the phosphoric, this acid may be decomposed by charcoal, but cannot be obtained in a concrete state. It has not yet been applied to any use. The salts formed with it are called *phosphites*.

What is FLUORIC *acid?*

The fluoric is an acid of a very peculiar nature‡, found in the fluor spar§. This mineral is a natural production, composed of fluoric acid and lime.

What are the properties|| *of fluoric acid?*

In the state of gas it is invisible, like air. Water

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‡ Fluoric acid is obtained by pouring sulphuric acid upon the powdered spar in a leaden retort, and applying a gentle heat. The sulphuric acid expels the fluoric, and unites with the lime in its stead. This acid has been discovered also in the enamel of the human teeth, and in ivory. Vauquelin has found it likewise in the topaz.

Fluor spar requires its own weight of concentrated sulphuric acid to disengage the fluoric acid gas, which must be condensed in water to form liquid fluoric acid. To preserve the liquid acid, it must be kept in bottles lined on the inside with wax dissolved in oil, or in vessels of lead or platina.

§ Fluor spar is found in many parts of Europe, particularly in Derbyshire. Some of it is so extremely beautiful that it is often employed in the manufacture of ornamental vases, &c. &c.

|| This acid has somewhat of the smell of muriatic acid, but is much more corrosive. According to Mr. Murray, it exceeds

rapidly absorbs it, and forms liquid fluoric acid. It has an acid taste, and the peculiar property of dissolving silex*. Its radical is not yet known.

What is the use of fluoric acid?

Fluoric acid has not been used except for etching upon glass†. It appears that it was

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all other acids in its saturating power, in as much as it neutralizes a larger quantity of any base. It acts so powerfully on silex, that it is impossible to use glass vessels for its distillation where any large quantity of the acid is required. A glass retort would be destroyed before a pound of the gas could be obtained. It combines with the siliceous earth of the glass, and carries it over with it in distillation.

Its action on glass may be shown by strewing a little powdered fluor spar on the surface of a pane of glass, and pouring a little sulphuric acid upon it. The sulphuric acid will disengage the fluoric acid from the spar, which will act upon the glass immediately as it becomes disengaged.

* If a small animal or reptile be exposed to the vapour of this acid drawn in glass, the animal moisture will absorb the acid, and the silex will be precipitated, so as to give it the appearance of a real petrifaction, or an animal covered with stone.

† I am informed that it is become a fashionable employment for young ladies to etch landscapes and other drawings on glass by means of this acid. They cover the surface of the glass with wax, and trace the drawing by cutting out the wax with proper instruments. The piece is then put into a leaden receiver, and the gas disengaged from the fluor spar by means of an Argand's lamp is thrown in upon it. In this way drawings of great beauty are made, as imperishable as the glass itself. A complete apparatus may be had of Messrs. Knights, Foster-lane, Cheapside, London, for about four guineas; it is so contrived,

first employed for this purpose in the 17th century[‡].

What is BORACIC *acid?*

The boracic is a peculiar acid separated from a substance called Borax[§]. The nature of its radical is still unknown[||].

What are the properties of boracic acid?

Boracic acid is in the form of thin scales[¶],

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that a lady may operate with it in a sitting-room with great safety; and by varying the process, the full effect of light and shade may be given to the drawings: for, if *liquid* fluoric acid be used, the lines will be transparent; whereas, if it be applied in the state of *gas*, they will appear dark and opake.

In France, barometers, thermometers, and other glass instruments, are graduated by means of this acid. It might be usefully employed for engraving labels on glass bottles designed to hold the corrosive acids.

[‡] Henry Swanhard, an artist of Nuremberg, having discovered the corrosive nature of this acid by observing its effect upon his spectacles, on which some had accidentally fallen, applied it to the purposes of engraving on glass so early as 1670.

[§] The boracic acid was discovered by Homberg in 1702. It may easily be procured by dissolving refined borax in hot water, and adding sulphuric acid till the solution has a slight acid taste. This is then to be left to cool and crystallize.

[||] See an account of Crell's experiments for the decomposition of this acid in Annales de Chimie, tome xxxv. 202. He has announced that carbon is one of its component principles.

[¶] This acid, when it is well crystallized, is in the form of small shining flaky crystals. If exposed to a strong heat, it becomes fused, and forms a solid white glass, which is sometimes employed in the composition of artificial precious stones.

slightly acid[*], and unalterable in the air. It forms the variety of salts called *borates*, when combined with the alkalies, some earths, and some of the metallic oxides. One of the peculiar properties of this acid is, that it imparts a green colour to burning bodies[†].

What is ARSENIC *acid?*

Arsenic acid is a compound of arsenic and oxygen. It is a heavy, thick, incrystallizable mass; very soluble in hot water[‡]; of an acid taste, and poisonous. With different bases it forms the salts called *arseniates.*

What is TUNGSTIC *acid?*

The tungstic acid is a tasteless yellow powder, composed of oxygen and tungsten[§]. It is inso-

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[*] The taste of this acid is bitterish, with a slight degree of acidity. It is very soluble in hot water, and but sparingly so in cold. It is very useful in the analysis of minerals, as it brings almost all the stones into solution. See Mr. Davy's late paper on this subject in the Philos. Trans.

[†] When burnt with alcohol it communicates a green colour to the flame, which becomes more and more green as the alcohol burns away. If a paper be dipped in alcohol and then sprinkled with this acid, it will burn with a green flame.

[‡] Arsenic acid is not affected by exposure to the air. It is composed of 65 parts of arsenic and 35 oxygen. It is made by giving an extra dose of oxygen to the common white oxide of arsenic, which of itself possesses several of the properties of an acid, and has by Fourcroy been called *arsenious* acid.

[§] Tungstic acid is found native in wolfram and other minerals. It may be obtained from wolfram by boiling three parts of muriatic acid on one part of the mineral. The acid is to be luble in water, but forms the salts called *tungstates,* by its union with alkalies, earths[||], or metals.

What is MOLYBDIC *acid?*

Molybdic acid is a white powder, composed of molybdenum and oxygen[¶]. It requires a large quantity of water to dissolve it[*]. When combined with salifiable bases, the compounds are called *molybdates.*

What is CHROMIC *acid?*

Chromic acid is an orange-coloured powder, composed of chromium and oxygen. It has an acrid metallic taste, is soluble in water, and cry-

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decanted off in about half an hour, and allowed to settle: the powder which precipitates is to be dissolved in ammonia; the solution evaporated to dryness, and the dry mass kept for some time in a red heat. It is then yellow oxide, or the tungstic acid in a state of purity. Dr. Thomson, vol. i. 250, 2d edit. This acid becomes blue by exposure to the light.

[||] Tungstic acid unites with the alkalies to saturation. It dissolves several metals, and assumes a *blue* colour in proportion as it abandons to them a part of its oxygen. Hume, Philosophical Magazine.

[¶] Molybdic acid was discovered by Scheele in 1778. It is procured from the sulphuret of molybdenum by distilling nitric acid off it repeatedly, till the sulphur and metal are both acidified; which is known by the conversion of the whole into a white mass. Hot water carries off the sulphuric acid, and leaves the molybdic in a state of purity. Dr. Thomson, vol. ii. 103.

[*] It requires 960 parts of boiling water to dissolve it. The solution is of a pale yellow.

stallizable. When mixed with different saline solutions it assumes a variety of beautiful colours; it also forms with the earths and alkalies various salts, called *chromates*[*].

What is the ACETOUS *acid?*

Acetous acid is principally obtained[†] from saccharine liquors[‡] which have undergone the vinous fermentation[§].

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[*] The chromic acid was discovered by Vauquelin. It is procured from the red lead-ore of Siberia. He obtained it by boiling 100 parts of this mineral with 300 of carbonate of potass and 4000 water, and separating the lead and the alkali by weak nitric acid. For an account of the different colours which this acid assumes, see Dr. Thomson, vol. ii. 105.

[†] In making vinegar, the casks should be only half filled; by this method a large surface of the liquor will be exposed to the atmosphere, from whence the oxygen is to be derived to acidify it.

[‡] All kinds of wine, and all sorts of malt or saccharine fermented liquors, are capable of yielding this acid. The smaller the quantity of the wine the sooner will it be converted to vinegar, provided there be a free access of atmospheric air. Ample directions for making vinegar will be found in Fourcroy's System of Chemistry, vol. viii. 250: but I believe the best treatise on this subject is by Citizen Parmentier, published in one of the volumes of the Annales de Chimie.

It is found that wine which contains most mucilage soonest becomes acid. On this account isinglass ought not to be added to wines, to fine them, till the moment of bottling them.

[§] It was formerly imagined that acetous acid could be prepared only from vinous liquors; but it is not an indispensable condition that it shall have been preceded by the vinous fermentation. This acid may be drawn from several kinds of

What are the properties of acetous acid?

Acetous acid, as it is usually prepared, is a pleasant yellow liquor, well known. When distilled it is colourless as water, and of an agreeable odour. In both states it is known in commerce by the name of vinegar‖.

What is the acid which has been usually called ACETIC *acid?*

Acetic acid is obtained from acetate of copper, acetate of soda, or acetate of potass. It was formerly thought to be a distinct acid; but it has lately been demonstrated by experiment to be merely *acetous* acid in a concentrated state¶.

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wood by the destructive distillation. Mr. Andrew Patten has a very large manufacture of this acid near Manchester, where the wood is burnt in large iron cylinders about 8 feet long and 3 feet diameter. The acid is chiefly used in making acetate of iron for the calico-printers.

According to recent experiments, it appears that acetous acid exudes with the perspirable matter from the pores of the human body. See Annales de Chimie.

‖ There is so little difference between the volatility of vinegar and water that it cannot be concentrated by boiling; but if it be mixed with charcoal dust, the charcoal will enable it to resist a strong heat, by which means the water may be thrown off by a boiling heat; and then the pure concentrated acetous acid may be drawn over in a proper apparatus by a stronger heat. We are indebted to Mr. Lowitz for this discovery.

¶ Darracq has shown that acetous and acetic acid both produced the same combinations, and gave the same products in their decompositions. He brought acetous to the state of acetic acid by distilling it several times over muriate of lime, *What are the properties of acetous acid in this state of concentration?*

Acetic acid thus prepared is pungent, acrid, and volatile*, and corrodes animal substances. With various bases it forms the salts called *acetates*†.

What is OXALIC *acid?*

The oxalic is a peculiar acid found in the juice of sorrel, in combination with potass‡. The

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and then was able to form as good ether with it as with the acetic acid obtained from acetate of copper. Annales de Chimie, tome xxvii.

[*] This acid evaporates entirely when exposed to the air; and when heated with free access of atmospheric air, it takes fire so readily that one is tempted to suspect the presence of ether in it. It dissolves camphor, and, with the addition of essential oils, forms the *aromatic vinegar.*

[†] Acetic acid may be advantageously employed to separate manganese from iron. When both metals are dissolved in this acid, and the solution evaporated to dryness, the acid adheres to the manganese, but abandons the iron. Water will then dissolve the acetate of manganese, and the oxide of iron will be left on the filter. Two or three evaporations and solutions are sufficient to deprive acetate of manganese of the whole of its iron.

[‡] Sal-acetosellæ, or the salt of sorrel of commerce, has usually been imported from Switzerland and the neighbouring countries, where it is prepared in large quantities from the juice of sorrel. According to Savary, one hundred pounds of the plant afford five ounces of the crystallized salt.

Deyeux has found a considerable quantity of this acid in chick peas. It was discovered by its burning the shoes of some persons who walked over a field of this pea. There is reason radical of this acid exists also in sugar and other matters, and requires only the addition of oxygen to form true oxalic acid[‡]. It crystallizes in four-sided prisms, has a very acid taste, and is soluble in water. It is composed of oxygen, hydrogen, and carbon.

What are the uses of oxalic acid?

Oxalic acid is of great use to us in detecting the presence of lime in solution[§]. It is also become an article of great consumption with the calico-printers, both in a state of purity and in combination with potash[||]. In combination with

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to believe that, by a chemical examination of other plants from which acid liquids spontaneously flow, this acid will be found to exist in greater abundance than has been suspected.

[‡] The oxalic radical appears to exist more abundantly in insipid matters than in sugar. Berthollet has obtained from wool more than half its weight of oxalic acid.

[§] The oxalic has a greater affinity for lime than any other acid; and as it forms with it an insoluble substance, it is the most proper test for discovering this earth. Thus, if a few drops of the solution of oxalic acid be dropped into a neutral solution of muriate of lime, an abundant precipitate of insoluble oxalate of lime will appear. I say a *neutral* solution of muriate of lime; for, if there be any excess of muriatic acid in the solution, the lime will be redissolved. Hence the superiority of oxalate of ammonia, to simple oxalic acid, as a test.

[||] The calico-printers have attempted to use the acidulous oxalate of potass instead of the citric acid; but it is so insoluble that they find a difficulty in making their solutions of a sufficient strength. The pure oxalic acid answers better for many purposes, as it is cheaper, and very soluble in water.

earths, alkalies, and metallic oxides, it forms the salts called *oxalates*[*].

What is TARTARIC *acid?*

Tartaric acid is a peculiar acid found in the cream of tartar of commerce[†]. It is capable of crystallization, and easily soluble in water. It is used by calico-printers to discharge false prints[‡]. The salts formed with it are called *tartrates.*

What is CITRIC *acid?*

Citric acid is found in the juice of lemons and several other fruits[§]. It crystallizes in beautiful

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[*] The oxalic acidule attacks iron, zinc, tin, antimony, and lead. It dissolves also the oxides of all the other metals, and forms with them triple salts. It is employed to take out ink spots from linen, &c., which it does by virtue of its attraction for iron.

[†] Tartar is procured from vessels in which wine has been kept. The tartaric acid appears to be a necessary substance in all wine; for it seems from some late experiments that *must* will not ferment if all the tartaric acid be taken from it. Dr. Thomson, vol. iv. 458.

[‡] Scheele was the first chemist who obtained tartaric acid in a separate state.

All the vegetable acids seem to be formed from the same radicals, viz. carbon and hydrogen, and, perhaps, in some there is also nitrogen; the different proportions of these, as well as of the oxygen, constitute the whole varieties.

[§] Scheele was the first person who obtained citric acid from the juice of lemons in a state of purity. When crystallized it suffers no alteration from exposure to the air, though it is said to change after some time when dissolved in water. This acid may be kept ready mixed with either of the dry carbonates of rhomboidal prisms; is extremely acid to the taste, and very soluble in water. It is used in various ways for domestic purposes, for medicine [||], and in the arts [¶]. The salts formed with it are called *citrates*.

What is MALIC *acid?*

Malic acid is obtained from the juice of apples, in which it exists ready formed [*]. It is a very acid, reddish-coloured liquid, composed, like the other vegetable acids [†], of oxygen, hydrogen and carbon. It is incapable of crystallization, and

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potass or soda; and, as no effervescence ensues till the mixed powder is put into water, we have a ready mode of making a pleasant saline draught.

[||] Within these few years an important use has been made of this acid in medicine. It is said that the largest dose of opium may be checked in its narcotic effects, if a proper quantity of citric acid be taken with it; and that with this adjunct it induces cheerfulness instead of stupefaction, succeeded by gentle and refreshing sleep. Dr. Willich on Diet, page 339.

[¶] This elegant acid is very useful to our manufacturers on account of its solubility. One ounce of cold water will dissolve 1¼ oz. of it, and boiling water will dissolve double its weight. The proper method of procuring it in crystals may be seen detailed in Ann. de Chimie, tom. xxii. See also Dr. Thomson, vol. ii. 146.

[*] The malic acid is found not only in apples, but in strawberries and other summer fruits. It was discovered by Scheele in the year 1785. For a method of procuring it, consult Dr. Thomson, vol. ii. 160.

[†] Malic acid by the addition of nitric acid is converted to oxalic acid.

has not yet been brought into any use except as a chemical test[*]. Its salts are called *malates*.

What is LACTIC *acid?*

Lactic acid is prepared from milk after the curd has been separated. It is incapable of crystallization, and has not hitherto come into use. The salts formed with it are called *lactates*[†].

What is GALLIC[‡] *acid?*

Gallic acid is found in the galls of commerce, and in most astringent vegetable substances[§].

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[*] Malic acid is of use in the analysis of earths for separating alumine from magnesia, as it forms with the former an insoluble salt, which precipitates, leaving malate of magnesia in solution.

[†] Fourcroy and Vauquelin have asserted, that the acid which is developed in milk is nothing but acetic acid modified by some animal substances and some salts which it holds in solution. Phil. Mag. vol. xxii. 176.

[‡] Gallic acid is soluble in 10 parts of cold water, and in 3 of boiling water. It is not altered by exposure to the air, but is decomposable by heat.

[§] Gallic acid exists in galls, in oak bark, and other vegetables, independent of the astringent principle. It is lately found that the property of giving a black colour to the solutions of iron is owing to this acid, and not to the astringent principle as was formerly supposed. A short process for procuring gallic acid in a separate state may be seen in Crell's Chemical Annals for the year 1787. It was Seguin who proved that the gallic acid and the astringent principle are different substances.

A German apothecary, named Tromer, says, that the excrescences on the roots of young oaks may be used with advantage as a substitute for galls. I believe oak saw-dust has been used in this country, instead of galls, to produce a black dye.

It is obtained in thin transparent plates, and in minute needle-shaped crystals, of an acid austere taste[||]. It has the property of precipitating iron, from its solution in acids; of a *black* colour[¶]. Its salts are called *gallates.*

What is MUCOUS *acid?*

Mucous, or saccholactic, acid as it has been called is obtained by nitric acid from gum arabic, and other mucilaginous substances. It is in

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[||] Several processes for procuring gallic acid may be seen in Thomson's Chemistry, or in Mr. Davy's papers in Journal Roy. Inst. and Philos. Trans.

For the method of analysing astringent vegetable substances, consult Mr. Davy's paper in the Philos. Trans. for 1803.

Every substance, an infusion of which precipitates gelatine, or animal glue, from its solution, possesses a tanning property. Its presence may be detected thus: Add a few drops of the solution of common glue to a wine-glass full of an infusion of the substance to be examined. If tannin be present the liquor will become turbid, and a whitish substance will precipitate, which is a true powder of leather. A table of the quantity of tan contained in twenty different kinds of bark, showing the comparative value of each to the tanner, may be found in the Philos. Trans. for 1799, drawn up by Mr. Biggin from actual experiments.

The gallic acid may be entirely freed from the tanning principle by means of muriate of tin. The tan will unite with the muriate of tin, and form with it an insoluble precipitate. There is reason to believe that tan is the source of the astringent principle in all astringent vegetables.

[¶] Gallic acid will not immediately give a black colour to green sulphate of iron in dyeing black, or in making ink. Exthe form of a white gritty powder, with a slightly acid taste. Its salts are called *mucites*[*].

What is BENZOIC *acid?*

Benzoic acid is prepared from a vegetable resin called benzoin[†]. It is a light whitish powder, with a peculiar and aromatic odour. Its taste is acrid and bitter. It is unalterable in the air, insoluble in cold, but soluble in boiling water[‡]. It is used in medicine under the name

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posure for some time to atmospheric air is necessary in order that the iron may thereby acquire a further dose of oxygen. A few drops of oxygenized muriatic acid will instantly produce the effect.

[*] Mucous acid was discovered by Scheele in the year 1780: for the method of obtaining it consult Dr. Thomson, vol. ii. 154.

[†] Benzoin is a resin procured from a tree which grows in the island of Sumatra. The acid procured from this resin has been known for 200 years. It is obtained from benzoin, in the form of flowers, by sublimation.

This acid is found also in balsam of Tolu, Peruvian balsam, liquid storax, and other similar substances. It has been likewise discovered in the urine of children, and of graminivorous animals; in blood; and in some of the species of fungi.

Vauquelin advises the collection of the urines of cattle, as proper for furnishing œconomically the benzoic acid. He recommends the decomposition of it by the muriatic acid.

[‡] Benzoic acid may be procured by boiling the resin with carbonate of soda, and adding, to the filtered decoction, diluted sulphuric acid as long as it produces any precipitation. The precipitate which forms, is the benzoic acid. See the last Edinburgh Dispensatory.

of flowers of benjamin[§]. Its salts are called *benzoates.*

What is SUCCINIC *acid?*

Succinic acid is prepared from amber[||]. It takes the form of shining white crystals, of a slight acid taste. It sublimes in a great heat.[¶] It is soluble in hot, but dissolves in small quantities in cold, water. It is useful as a re-agent[*], but of no use in the arts. Its salts are called *succinates.*

What is CAMPHORIC *acid?*

Camphoric acid is prepared from camphor by

[§] The best flowers of benzoin are of a brilliant white, entirely soluble in alcohol, and likewise, though more sparingly, in boiling water; and leave no ashes when evaporated by heat.

[||] Amber is a transparent combustible substance, dug out of the earth, or found upon the sea coast. It manifests electricity by friction, and was much admired by the ancients as an ornament of dress. The amber-pits of Prussia are said to afford the king a revenue of 26,000 dollars annually.

[¶] Succinic acid may be obtained thus: Fill a retort half way with equal parts of powdered amber, and dry sand; lute on a receiver, and distil in a sand-bath with a gentle heat. The succinic acid will attach itself to the neck of the retort. It is generally coloured by a portion of oil which comes over in distillation; but it may be purified by pouring nitrous acid upon it, and then expelling the nitrous acid by a heat not sufficient to drive off the succinic acid.

[*] When combined with ammonia this acid becomes a valuable re-agent, by the property of separating iron from its solutions, and not operating upon other metals. Thus, if a little of this succinate of ammonia be added to a solution of sulphate

means of nitrous acid*. It is in very white crystals, which have a slightly acid, bitter taste, and a smell like saffron. It is very insoluble, requiring nearly 200 times its weight of water to dissolve it. With salifiable bases it forms *camphorates*.

What is SUBERIC *acid?*

Suberic acid is prepared from cork, by means of nitrous acid†. Its taste is acid; it is generally seen in the state of powder, and is not crystallizable. Boiling water dissolves half its weight, but it is very insoluble in cold water. Its salts are called *suberates*.

What is LACCIC *acid?*

Laccic acid is procured from a substance called *white lac*‡. It has a bitter saltish taste, but not

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of iron, a succinate of the metal will be precipitated. It may be calculated that every 100 grains of the precipitate contain 68 grains of iron.

[*] Camphor is a white crystalline substance of a very strong taste and smell, obtained in the East from a species of laurel. It is so inflammable that it burns even on water. La Grange's different processes for preparing this acid are translated by Mr. Nicholson, and published in vol. ii. of his Journal, 4to.

[†] This acid was discovered by Brugnatelli in the year 1787. He gave it the name suberic acid from *suber*, the Latin name of the cork-tree. This chemist has lately noticed that suberic acid in considerable quantities may be obtained from paper, by treating it with nitric acid.

[‡] White lac is a peculiar substance brought from the East

at all sour §. It crystallizes in needle-like crystals.

What is PRUSSIC *acid?*

The prussic is a peculiar acid, composed of hydrogen, nitrogen, and carbon. It is a colourless liquid like water, has a sweet taste, and does not alter the colour of vegetable blues. It is of great use to chemists for detecting metals in solution ‖. It is prepared from blood and other animal substances ¶; and, when united with iron, forms that beautiful colouring substance called prussian blue*.

Indies. This substance, which has a resemblance to bees'-wax, is secreted by an opaque and rough insect, of a gray colour.

§ Laccic acid was discovered by Dr. Pearson. It is generally in a fluid state. Its specific gravity at 60° is 1.025, and when heated it has the smell of newly-baked bread.

‖ The colour of the precipitate indicates what metal, and its quantity enables us to ascertain the proportion of such metal contained in the solution to be examined. For this purpose the acid must previously be combined with an alkali or an earth. Prussiate of potass is generally used.

¶ A method of obtaining prussic acid in a state of absolute purity has lately been announced; viz. by distilling a mixture of two parts of prussian blue, one of sulphuric acid, and one of water.

There is great reason for believing that prussic acid does not contain oxygen. The grounds on which this supposition is founded may be seen in Berthollet's Chemical Statics, vol. ii. 222.

* Prussian blue was discovered by accident in the year 1709;

What is SEBÁCIC *acid?*

Sebacic acid is procured from animal fat or tallow. It has an acid, sharp, bitterish taste*. It combines with alkalies, earths, and metallic oxides, and forms the salts called *sebates.*

What is URIC *acid?*

The uric or lithic acid is found in human urine†. Some of the human calculi are composed entirely of this acid. It has neither taste nor smell, but it reddens vegetable blues, and combines with alkalies and earths. It is a com-

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but it was not till the year 1775 that Bergman ascertained that this colouring matter was a peculiar acid. Scheele, however, was the first who explained its nature and composition, in the year 1782, announcing that he had formed it without animal matters, and that it is a compound of ammonia and charcoal. Later experiments of Berthollet show that this acid does not contain ammonia ready formed, but that it is a compound of carbon, hydrogen, and nitrogen.

The process to prepare prussian blue may be seen in Neumann's Chemistry, vol. i. 106; in Shaw's Lectures on Arts, 8vo. 180; or in Bouillon La Grange, vol. ii. 354. The Journal de Physique for the year 1778 describes the process as it is conducted in the manufactories of Germany.

* Sebacic acid crystallizes in needles, and when heated liquefies like tallow.

For further information respecting this acid, consult Nicholson's Journal, vol. i. 8vo. 34; and Thenard's memoir in Annales de Chimie, tome xxxix. 193.

† If the urine of a healthy person, voided in the morning after sleep, be preserved, the liquor will in a few hours present a light cloud which occupies the upper part of the vessel;

position of carbon, nitrogen, hydrogen, and oxygen.

What is the AMNIOTIC *acid?*

Amniotic acid is obtained from the liquor of the amnios of the cow. It is slightly acid; it reddens the tincture of turnsol; and may be obtained in white crystals‡.

How many different distinct acids are there?

The whole of the acids now known amount to about thirty, besides what are formed by some of those acids combining with different proportions of oxygen §.

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this cloud, gradually augmenting in quantity, subsides, and becomes a sediment of small red crystals, with brilliant facets: this sand of the urine, is *uric acid.* As this acid precipitates, the urine loses its colour, in a great measure; its acid nature disappears, and it becomes ammoniacal and exhales that smell.

‡ The amniotic acid was discovered by Vauquelin and his coadjutor Buniva. It dissolves readily in hot water, and but slowly and sparingly in cold. In order to obtain it, nothing more is necessary than to evaporate the liquor of the amnios of the cow to one fourth, and leave the remainder to cool, which will be found to contain the acid in crystals.

The mellitic and the columbic acids I have not noticed in the text, because the minerals from which they are procured are so rare that few chemists will ever be likely to obtain even a specimen of them.

§ The acids are such powerful agents in a variety of chemical changes which take place in nature and in the arts, that it is of the utmost importance to acquire a knowledge of the modes in which they operate. Let it be recollected then, that

What are the uses of these various acids?

The uses of the acids are so many and important, that it is impossible to enumerate them. They are indispensable to various arts* and manufactures †; are employed for culinary pur-

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there are two ways in which the acids produce changes in the substances with which they are brought into contact. In some cases they effect an union with these substances, and become a part of the new compound, without having themselves undergone any decomposition. In others they become partially decomposed, by affording a part of their oxygen to the bodies on which they operate. The formation of common salt by the union of muriatic acid with soda is an instance of the first of these cases, and the action of nitrous acid on iron will exemplify the latter.

* Sulphuric acid, in a diluted state, is used by the tanner in the operation called scouring; also by the dyer, in a concentrated state, for dissolving indigo. It is likewise employed by hatters. Silk-dyers use it for whitening silks, and for giving them a beautiful lustre. The chemist employs it in the preparation of nitrous and muriatic acid, and as an agent in a variety of processes and decompositions.

Nitric acid is used by dyers to make their solutions of tin. Silver-refiners employ it in the operation of *parting.* It is also used by gilders, brass-founders, calico-printers, colour-makers, &c.

Muriatic acid is employed in dyeing, calico-printing, and colour-making. The oxygenized muriatic acid, in bleaching, &c.

† The arsenic, acetous, oxalic, tartaric, citric, gallic, and prussic acids are all of them employed in the different manufactures of the country.

poses ‡, and for medicine §: they act an important part in the great elaboratory of nature; produce that numerous class of bodies called salts; and form many of the rocky and mountainous parts of the globe we inhabit.

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‡ The acetous, the tartaric, and the citric acids are used for culinary purposes. According to some experiments of Dr. Macbride, it appears that all the mineral acids in a diluted state might be employed with great advantage in preserving meat. They probably owe their antiseptic qualities to oxygen. Muriatic acid drawn in glass would, I believe, in a state of great dilution, be a pleasant and wholesome condiment for our food. It was formerly used in this way. The celebrated Rudolph Glauber, who was the first to turn the residuum which is left after the distillation of this acid to a good account, describes the several ways in which it was used in the kitchen in his time, page 12 of his Treatise on Philosophical Furnaces. That this acid possesses valuable antiseptic qualities there can be no doubt. Sir William Fordyce gives an account of a dry-salter who acquired a large fortune from possessing a secret that had enabled him to send out to the Indies provisions in a better state of preservation than any of the trade. His whole secret was that of putting a small quantity of muriatic acid into each cask.

§ Great advantages have already been obtained from the use of many of the acids in medicine, particularly the mineral acids. As to the *oxygenized muriatic acid*, "I will venture to affirm that it will hereafter be one of the most useful of the materia medica. It is known that it is strongly tonic; that it augments the force of the stomach and the whole system, and acts even as a specific in syphilitic disorders." Fourcroy.

Parliament voted a reward of 5000*l.* to Dr. Carmichael Smyth, for his discovery, that nitrous acid, applied in the state of vapour, effectually destroys contagion, especially typhus, *Do you recollect any instances of acids entering into the composition of rocks and mountains?*

The vast masses of limestone, chalk, and marble, which are found in every part of the world, are combinations of lime and carbonic acid*: the mountains of gypsum in the vicinity of Paris and elsewhere are combinations of lime and the sulphuric acid †. The fluor spar of Derbyshire owes its compactness, &c. to the fluoric acid ‡; and there are mountains of common salt both in the eastern and western hemisphere, which contain hundreds of millions of tons of muriatic acid §.

Are you sure that the acids which Nature has employed in the formation of mountains are of the

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jail, yellow and such like fevers. The most simple process for this purpose, is that invented by Mr. Hume, who assisted the Doctor in his experiments. See Smyth on Nitrous Vapour.

Dr. Thornton says that he has cured syphilitic complaints by nitrous acid, in cases where mercury has failed. Medical Extracts, vol. v. 406. Mr. Cruickshank, of Woolwich, has given it with the same intention, and with the best success.

* Limestone, chalk, and marble, are composed of about 50 parts acid and water, and 50 parts lime.

† Gypsum is composed, according to Bergman, of 32 parts of lime and 68 of acid and water.

‡ There are however some varieties of this salt which contain different portions of acid.

§ Common salt, according to the analysis of Kirwan, is composed of 53 parts soda, 39 acid, and 8 water.

same kind as those which come under our common notice and observation?

Yes: any of these substances may be decomposed, and their acids exhibited in a state of purity for experiment or use||.

Do you know of any other natural productions which are indebted to the acids for their natures and properties?

The large masses of alum ores and of ponderous spar in different parts of the earth owe their origin to the sulphuric acid; the chrysolite of Greenland is a compound of alumine and the fluoric acid; and several of the precious stones are combinations of the different earths with the chromic or the phosphoric acids ¶; not to mention the annual changes which the vege-

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|| If the pupil be directed to pour a little diluted sulphuric acid upon some pieces of marble, the carbonic acid will be disengaged, and become evident to the senses. In like manner he may disengage the fluoric acid from the fluor spar, the muriatic acid from rock-salt, and other acids from those minerals in which they are found native. A few experiments of this kind will serve to show him how abundantly the mineral acids occur in Nature.

¶ Mr. Parkinson thinks that the emerald owes its colour to the oxide of chrome, and the ruby to the acid of that metal. According to Vauquelin, the ruby is a combination of the chromic acid, alumine, and magnesia.

The chrysolite seems to be composed of lime and the phosphoric acid. See Ann. de Chim. xxvi.

table kingdom undergoes by the formation and loss of the vegetable acids.

You speak of the formation of acids: Are bodies of this class formed and decomposed by the common operations of nature?

Many of these bodies are not only formed artificially; as has been before said, by the direct union of their radicals with oxygen, but we have reason to believe that this is perpetually done by natural means; and that the acids are the principal agents in those chemical changes which the various substances of this earth are destined to undergo*.

What may we infer from this constitution of things?

From hence we have reason to believe that the great and beneficent Creator has provided such an immense store of all the different elementary materials with which this our world is composed, that no scarcity of those things which

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* "Mr. Baumé, by a series of ingenious experiments, discovered that clays may be produced by the action of the sulphuric acid on vitrified substances. Mr. Ferber applied this fact to the grand operations of Nature on the matters ejected by volcanos: he discovered a fine white argillaceous matter in the hollow part of vitrified lava, evidently produced by the action of the sulphuric acid. Hence it appears that those substances which have by the action of fire been rendered otherwise intractable, again become, by the action of the sulphuric acid, subservient to vegetable life." Parkinson. See Ferber's Letters.

are subservient to the wants and comforts of its inhabitants could ever happen, whatever changes it might undergo, though it should be destined to revolve in its orbit for millions of years yet to come †.

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† When we consider the various properties of matter, and the variety of changes it is calculated to undergo for the use, the gratification, and the accommodation of man—we are ready to exclaim—

> " We feel the present Deity, and taste
> The joy of God, to see a happy world."

CHAP. VIII.

OF SALTS.

What is a salt?

When an acid * is combined with an alkali, an earth, or a metallic oxide, it forms what is called a salt. Such compounds were formerly called *neutral* salts; but that term is now applied only to those salts in which there is no excess either of acid or of base †.

How many salts are there?

As the acids are capable of forming various combinations with the different earthy, alkaline, and metallic bases, the precise number of the

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* Acids may be considered as true *salifying* principles, and the substances with which they unite to form salts may be called *salifiable* bases. Lavoisier.

† To give the pupil a clear idea of this class of bodies, it may be advisable to set him to form some of the salts from their component parts. He might be directed to pour a little sulphuric acid into a solution of soda in water, to evaporate the superfluous water, and then to notice the crystallization of the new-formed salt: if the liquor be allowed to stand quietly for a few hours in a cool place, he may observe the salt shoot into beautiful crystals of sulphate of soda.

salts is not known‡. Probably they amount to nearly two thousand §.

What method has been taken to distinguish the different salts?

Modern chemists have adopted a new nomenclature for this purpose, which is simple, ingenious, and useful ||.

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‡ Fourcroy reckons that there are 134 *species* of salts; but how many distinct salts there are he has not calculated.

Having 32 acids and 57 bases, it would appear at first sight that there are 1824 salts: but there are several of the metallic oxides which cannot combine with many of the acids; which is also the case with silex, one of the earths. However, to compensate for this deficiency, there are several acids capable of combining with two bases at once. These are called *triple-salts*. Besides these there are super-salts, and sub-salts.

§ Should any one express his surprise that the number of one class of bodies should be so great, he may be told that Nature seems to aim at variety in all her productions. Saint Pierre informs us that there are 6000 species of flies, and 760 different butterflies. Ray computed the number of species of insects at ten thousand. There are above 1000 different species of beetles in Great Britain.

|| This nomenclature was drawn up by a society of French chemists, soon after the new theory of chemistry was announced by Lavoisier; and most of the French writers arrogate great honour to their nation, on both these accounts. But it may very fairly be remarked, that had it not been for the previous discoveries of Dr. Black, Dr. Priestley, and Mr. Cavendish,—Lavoisier could never have had the honour to form such an admirable system of chemistry.

How are the salts distinguished by this nomenclature?

Every salt has a double name, one part of which indicates its acid, and the other its base; so that, in a collection of many hundred different salts, the composition of each is immediately known by its appellation*.

Can you explain the manner in which this is effected?

All substances which are compounds of metallic oxides, earths, or alkalies with the sulphuric acid, are called *sulphates*; with the muriatic acid, *muriates;* with the nitric acid, *nitrates*; with the carbonic acid, *carbonates*, &c. &c.†

Do the advantages which we derive from this nomenclature compensate for the inconvenience of changing the names of so many substances?

The new nomenclature, by its scientific classi-

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* Fourcroy has well remarked that if this arrangement had not been made, it would have been absolutely impossible to know the characters of the numerous salts which have been discovered, and the science of chemistry would then have been confined to the very few men who are capable of extraordinary efforts of memory.

† These are the terms generally made use of in chemical language, but sometimes, in order to prevent monotony, we give an adjective termination to the word which expresses the base of the acid. Thus we say calcareous salts, instead of salt of lime; ammoniacal salts, instead of salts of ammonia; alu-

fication of bodies, gives such a facility to the acquisition of chemical knowledge, that this alone would have been sufficient to have justified chemists in adopting it; but its contrivance for pointing out the *nature* of the substances bearing the new names, gives it advantages far surpassing every inconvenience attending the alteration[‡].

Describe the nature of some of these advantages.

The saline compound, formerly called *Glauber's* salt, is now called sulphate of soda, for it is a combination of sulphuric acid and soda[§]; what was called *gypsum*, or plaster of Paris, a compound of lime and sulphuric acid, is now called sulphate of lime; in like manner what was called *green copperas*, is now sulphate of iron, that substance being a compound, not of copper,

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minous salt, instead of salt of alumine; and with the same design, the terms barytic, magnesian and the like are used.

[‡] As the boundaries of chemical science have been extended, the number of known salts has been surprisingly increased; so much so, that it would have been impossible to recollect the nature of each, without the assistance of a nomenclature of this kind. Thirty years ago not more than 20 or 30 species were known; since then more than 100 new species, comprising upwards of a thousand distinct salts, have been added to the list.

[§] It is necessary to remark, that when an acid is combined with *two* bases, the names of both are subjoined to that of the acid. Thus we say sulphate of alumine and potass, and tartrate of potass and soda.

as the old name seemed to import, but of *iron* and the sulphuric acid*.

Have the framers of this nomenclature been equally happy in the choice of names for the salts which are composed with the other acids?

Yes; the principle upon which the nomenclature is formed is such, that the composition of every salt is designated by an appropriate name with the utmost perspicuity.

According to the new nomenclature, what is the common culinary salt called?

Common salt is called *muriate of soda*†; that is, a composition formed of soda and muriatic acid.

What do you call salt-petre?

Salt-petre is called *nitrate of potass;* it being composed of potass and nitric acid.

What is chalk now called?

Chalk, being a compound of lime and carbonic acid, is called *carbonate of lime.*

You have said that these bodies were formerly called neutral *salts, why is not that term now applied as before?*

No salt can strictly be called *neutral,* except

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* It would be easy to make out a long list of substances with names equally improper, and which have characteristic and appropriate names assigned them in the new nomenclature.

† Formerly the word SALT was confined to muriate of soda. No other substance was then known as a salt. Afterwards,

such in which the acid is completely neutralized by the base, and the base by the acid, so as to be mutually saturated by each other[‡].

Is not that the case with all saline compounds?

No: some have an excess of acid, as cream of tartar; and other salts have an excess of base, as common borax.

How are such salts distinguished?

When a salt is found to contain an excess of acid, the preposition SUPER is prefixed to its name[§]; but when it does not contain a sufficiency of acid to saturate the base, the preposition SUB is added; as super-tartrate of potass, and sub-borate of soda[‖].

Some salts are formed with acids not fully oxy-

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the acids and alkalies were called salts also. There are innumerable proofs of this in the old chemical writings.

[‡] The propriety of restricting the use of the term *neutral* will appear, if we consider that we have some bases that combine with more than one dose of acid, and thereby form salts which differ in their appearance and properties. Thus we have *sulphate* of potass, and *super*-sulphate of potass. The one is a neutral salt, the other is a salt with excess of acid.

[§] Many of these super salts may be discovered by carbonate of magnesia. If an acid be present in the solution, an effervescence will take place on the addition of the carbonate.

[‖] We are indebted to Dr. Pearson for this mode of distinguishing these salts. Before his method was adopted, the former of these salts was called tartrate of potass with excess of acid, or acidulous tartrate of potass; and the latter borate of soda with excess of base.

genized, as the sulphurous and phosphorous acids: how are such salts distinguished?

All salts composed with acids ending in *ous*, take an ending in *ite*, instead of *ate*. Thus we say *sulphite* of lime, or *phosphite* of potass*.

What are the generic characters of the SULPHATES?

The sulphates† have generally a bitter taste; are precipitable from fluids by a solution of barytes; and afford sulphurets when heated red-hot with charcoal‡.

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* When sulphur is fully saturated with oxygen it forms what is called sulphuric acid, and the salts composed with this acid are called sulphates. But when sulphur is partially oxygenized, an acid is produced called sulphurous acid, and the salts formed with it are called sulphites.

The new nomenclature enables us to distinguish between acids which are partially oxygenized, and those which contain a maximum of oxygen. This is of great importance, because the properties of the salts formed with these acids vary as much as the acids themselves. The salts formed with acids ending in *ic* are generally permanent; whereas salts formed with the same bases combined with acids ending in *ous* are seldom permanent, but by exposure to the air attract oxygen, and are changed into salts of the former kind.

† The quantity of sulphuric acid contained in any of the sulphuric salts may be known by means of barytes. For if any of the solutions of this earth be added to a solution containing sulphuric acid, a sulphate of barytes will instantly be formed and precipitated. When this precipitate is dried, every hundred grains of it will (according to Chenevix) contain 24 grains of sulphuric acid.

‡ When a sulphate has been converted to a sulphuret by

Can you enumerate a few of the principal sulphuric salts?

Among the first of them are sulphate of barytes§, sulphate of strontian, sulphate of potass, sulphate of soda, sulphate of lime‖, sul-

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burning with charcoal, the sulphuret may be decomposed, and the sulphur precipitated by the addition of muriatic acid. For a method of decomposing these salts in a large way, consult Encyclopædia Britannica, Chemical Index, article *Vitriolated Tartar*.

To analyse the earthly sulphates, heat them to whiteness, in order to find the quantity of water which they contain; then boil them with carbonate of potass, which will occasion their decomposition. A common Florence oil flask is sufficient for this purpose. It may be ascertained when it has been sufficiently boiled by taking a little of the earth from the bottom of the flask, and trying it with muriatic acid. If the muriatic acid dissolves it entirely, the decomposition is complete.

§ Sulphate of barytes, or *ponderous spar* as it has been called, is abundant in different parts of the earth. Sulphate of strontian is found in Scotland and elsewhere in abundance. Sulphate of potass, sulphate of soda, and sulphate of ammonia are prepared by chemical manufacturers in many of their processes. Sulphate of lime, sulphate of magnesia, and sulphate of alumine are native productions. Sulphate of ammonia, it has been said, has been found native in the neighbourhood of volcanos.

‖ Sulphate of lime is gotten in abundance in Staffordshire, Derbyshire, and other counties of England. The hills around Paris are composed entirely of this earthy salt. Hence its name *plaster of Paris*. When burnt and ground it is miscible with water, for which it has so great an affinity that it becomes solid almost immediately. This property renders it an excelphate of magnesia, sulphate of ammonia, and sulphate of alumine*.

What are the generic characteristics of the SULPHITES?

The sulphites have always a disagreeable sulphurous taste; they are decomposed or changed by the nitric, muriatic and some other acids which do not affect *sulphates*; if exposed to fire

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lent substance for forming busts, cornices, &c. which are very durable, if protected from the weather, and not exposed in damp situations. In America this substance is used as a manure.

[*] Alum is prepared near Glasgow, by Messrs. Mackintosh and Knox, at a much less expense than it can be made at Whitby, as it is there found ready formed in a state of silky efflorescence, and only requires to be dissolved and crystallized for sale. It seems that a large quantity of aluminous schist was laid bare by the working of a coal pit, at least 200 years ago; and that the action of the atmosphere during this period has completely acidified it, and converted it into a crystallizable salt. Whenever this is consumed, I apprehend the work must be discontinued, on account of its inland situation; for as every 100 tons of alum slate afford more than 90 tons of refuse, any work in the interior of the country would soon be blocked up by it. At Whitby this refuse is thrown into the sea, as it occurs.

Vauquelin distinguishes seven different kinds of sulphate of alumine. It was he who first proved that soda is of no use in the formation of alum. He afterwards showed, that if a few drops of solution of potass, or of sulphate of potass, be added to an uncrystallizable solution of sulphate of alumine, the crystallization will immediately commence. See Annales de Chimie, tom. xxii.

they yield sulphur, and become sulphates; and are converted into sulphates even by exposure to the action of the atmosphere[†].

Can you enumerate some of the sulphurous salts?

The principal are, the sulphites of barytes, of lime, of potass[‡], of soda, of ammonia, and of magnesia.

What are the generic characteristics of the MURIATES?

The muriates, when acted upon by concentrated sulphuric acid, yield muriatic acid in the visible form of vapour; and when by the nitric acid, oxygenized muriatic acid gas. They are the most volatile, and yet the least decomposable by fire, of all the salts; not being perceptibly altered by combustibles, even when assisted by heat[§].

[†] See a memoir on these salts by Fourcroy and Vauquelin, in vol. xxiii. of Ann. de Chimie.

[‡] The *sulphites* were first pointed out by Stahl. Sulphite of potass was the first of these salts that he examined. From this circumstance it acquired the name of sulphureous salt of Stahl.

These salts are mostly formed artificially, by saturating the alkaline and earthy bases with sulphurous acid. For the easiest method of conducting the process, consult Thomson's Chemistry, vol. ii. 449.

[§] This is an evident, and at the same time a most remarkable character of this species of salt. Muriate of soda may be volatilized by heat, but if the vapour be collected it will

Can you enumerate the chief of the muriatic salts?

The principal of the muriatic salts are the muriates of barytes, of potass, of soda*, of

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be found still to be muriate of soda. Some years ago I exposed several hundred weights of this salt to a most intense heat in a reverberatory furnace for 48 hours, with a view to decompose it; but when it was removed from the furnace there was no change, it remained muriate of soda. Another portion was kept in a state of fusion for 36 hours with a considerable quantity of carbonaceous matter, but no decomposition was effected.

* Muriate of soda is the salt which has been longest known. It is our common culinary salt, and is supposed to furnish the necessary supply of soda to preserve the bile in an alkaline and antiseptic condition.

This salt is of great use in the animal creation; horses are very fond of it; and cows give more milk when supplied with it. Dr. Mitchil relates, that in the back settlements of America, wherever this salt abounds, thither the wild beasts of the forests assemble to regale themselves; and that some of these places are so much frequented, that the ground is trodden to mud by them. The natives call these spots *licks*, or licking-places. In some parts of Africa, large herds of cattle travel from great distances at stated seasons to enjoy the marine plants which grow on the coast and are saturated with sea-salt. The fattening property of our own salt-marshes is well known to graziers and farmers.

Whenever the finances of this country are in a state to allow the duty to be withdrawn, the greatest improvements in agriculture may be expected from the use of sea-salt. Mr. le Goux, in his history of the cocoa-nut tree, tells us that the inhabitants of those parts of Hindostan and China which border on the strontian, of lime, of ammonia, and muriate of magnesia†.

What are the generic characteristics of the HYPEROXYGENIZED MURIATES‡?

The hyperoxygenized muriates yield very pure oxygen gas by the action of fire, and are thus converted to common muriates: the strong acids expel the hyperoxygenized muriatic acid from

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sea-coast sprinkle their rice-fields with sea-water, and use no other manure; and that in the interior of these countries they sprinkle the lands with salt before they are tilled; and that this practice has been followed for ages with the greatest advantage.

In a conversation with a gentleman who has spent many years of a valuable life in making experiments on the employment of salt in agriculture, and in endeavouring to procure an act of parliament to sanction its use, I was informed that one bushel to an acre makes land always more productive; but that a large quantity would for 2 or 3 years afterwards render it actually sterile.

† Muriate of potass has been found native in the bogs of Picardy: this salt was formerly, and is still, much used by some alum-makers to procure the crystallization of alum. Muriate of ammonia is the common sal ammoniac of commerce. Muriate of barytes and strontian are both factitious salts. Muriate of lime is found native in various states; it is also furnished in abundance by the makers of carbonate of ammonia: it is used for the production of artificial cold. When dissolved in alcohol it burns with a flame of a beautiful red colour, especially if the solution be agitated during the inflammation. Muriate of magnesia is found in mineral and in sea waters.

‡ The hyperoxygenized muriates were discovered by Berthollet in 1786.

these salts, without the assistance of heat*. When mixed with combustibles, they detonate with great violence by mere friction or percussion, and sometimes spontaneously †.

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* Those salts which have been called oxygenized muriates have been proved by Mr. Chenevix to be hyperoxygenized muriates; that is, the acid which forms these salts is in the highest degree of oxygenizement. He was desirous of exhibiting this acid in a separate state: but when he attempted to obtain it from only 500 grains of hyperoxygenized muriate of potass, the retort burst with a loud report, and was reduced almost to powder, so that scarcely any fragment of it could be found in the laboratory. Dr. Vaudier, who was present, was near losing his sight by the explosion. Phil. Trans. vol. xcii. 126.

The component parts of this salt are, hyperoxygenized muriatic acid 58 parts, potass 39, water 3 parts.

† Of this salt Fourcroy remarks, that "it seems to include the elements of thunder in its particles. A chemist can produce effects almost miraculous by its means, and Nature seems to have concentrated all her power of detonation, fulmination and inflammation in this terrible compound." By *gently* triturating 3 grains of this salt and one of sulphur in a mortar with a metallic pestle, a series of detonations takes place resembling the cracks of a whip. If struck on an anvil, the report is as loud as a gun. But too great caution cannot be exercised in the use of this salt. Three parts of it with half a part of sulphur and half a part of charcoal produce most dreadful and violent explosions. But the shocking death of two individuals in October 1788, and the burns which others have suffered by it, render it feared by chemists in general. If the aforesaid mixture of this salt be thrown into concentrated sulphuric acid, a flame is developed so strong and brilliant that the eye can with difficulty support it. Fourcroy, vol. iii. 313. It should be remembered that the mixture

Can you enumerate the hyperoxygenized muriates?

The chief are; the hyperoxygenized muriates of potass ‡, of soda, of barytes, and of lime.

What are the generic characteristics of the NITRATES*?*

The nitrates yield oxygen gas mingled with

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must always be made moist, and never kept *ready* mixed, as it is liable to explode spontaneously.

That such a mixture will explode spontaneously, was experienced by a friend of mine, above 20 years ago. He had a phial, containing not more than two drachms of the powder, placed on a shelf with other bottles; and after remaining quiet for many months, it exploded, attended with a tremendous report, and the destruction of most of the bottles near it. The temperature of the place was uniformly about 65° Fahrenheit.

‡ Hyperoxygenized muriate of potass is used not only for experiment, but also in medicine. From its explosive effects, Berthollet was induced to propose it as a substitute for nitre in the manufacture of gunpowder. The attempt was made; but no sooner did the workmen begin to triturate the mixture than it exploded with violence, and proved fatal to two individuals who were near it. Phil. Trans. xcii. 128. I have, however, reason to believe that gunpowder made with this salt, was afterwards actually used by the French in one of their campaigns. See Additional Notes, No. 56.

Berthollet is of opinion that in this salt the oxygen retains all the caloric which it had when in a gaseous state. The concentration of the oxygen gas by its union with the potass, is probably sufficient to account for its explosive effects. See the last note, page 97.

A solution of this salt well mixed with common soap in a mortar, is said to improve the soap so as to render it fitter nitrogen gas by the action of fire; they give out a white vapour of nitric acid when acted on by concentrated sulphuric acid; and when mixed with combustible substances produce at a red heat inflammation and detonation[*].

Can you enumerate some of the nitric salts?

The more noted are; the nitrates of potass[†],

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for shaving than any of the kinds recommended for that purpose.

The other hyperoxygenized muriates are also prepared by art, and are of little use, except the hyperoxygenized muriate of lime, which is employed in bleaching.

[*] This may be shown by heating a little nitre in a crucible, and throwing powdered charcoal upon it. The charcoal will combine with the oxygen of the nitrous acid, and pass off in the state of carbonic acid gass; except the part that combines with the potass, and remains in the crucible.

[†] Nitrate of potass, or salt-petre, is generated by nature in abundance, particularly in the East: it appears that nothing is necessary for its production but the presence of lime, heat, and dry atmospheric air. The atmosphere furnishes the acid; but how the potass is given to it is not known.

Notwithstanding the prodigious quantity of salt-petre collected in the East Indies, it has been calculated, that two thirds of the whole are annually sent into China and other parts of Asia to make artificial fire-works. The fire-works of the Chinese exceed those of all other nations in variety and beauty.

At Apulia near Naples there is a natural nitre-bed, in which the earth contains 40 per cent. of nitre. Pelletier has published a memoir on the analysis of this valuable treasure, in the Annales de Chimie, tome xxiii.

In Switzerland, the farmers extract an abundant quantity of very fine salt-petre from the earth under the stalls of their of barytes, of soda ‡, of strontian, of lime §, of magnesia, and of ammonia.

What are the generic characteristics of the CARBONATES?

All the alkaline carbonates are soluble in water; those of the earths and metals are nearly insoluble, unless the acid be in excess; and they

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cattle. The urine of quadrupeds contains much potash, and this acquires nitric acid from the atmosphere. See Additional Notes, No. 22.

In the reign of Charles the First, great attention was paid to the making of salt-petre in England. Certain patentees were authorized by royal proclamation to dig up the floors of all dove-houses, stables, &c. the proprietors at the same time being prohibited from laying such floors with any thing but mellow earth.

Nitre is used in large quantities in the manufacture of gunpowder, every 100 parts of which are composed of 76 parts nitre, 15 charcoal, and 9 sulphur. The best account we have of this manufacture was published by Mr. Coleman, the superintendant of the Royal Powder-mills, in the Phil. Mag. vol. ix. 355.

When it is considered that nitre was known, and in use, *long before* it was distilled for aqua-fortis, or employed in the manufacture of gunpowder; what encouragement does this afford to chemists, to investigate the properties of every new substance which comes under their observation!

‡ Nitrate of soda, according to Bowles, has been found native in Spain.

§ Nitrate of lime is generally found native with salt-petre. This salt, if properly heated, becomes luminous in the dark, and forms what is called Baldwin's phosphorus.

all effervesce and give out the carbonic acid, when treated with the stronger acids*.

Endeavour to enumerate the principal carbonates, or bases combined with this acid.

The carbonates of barytes†, of strontian, of lime‡, of potass, of soda, of magnesia, and of ammonia, are the principal carbonates that occur.

What are the generic characteristics of the PHOSPHATES§?

The phosphates are fusible either into opaque or transparent glasses; are phosphorescent at a

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[*] There are eleven species of carbonic salts at present known. There are, however, only four of the native earths found combined with this acid, viz. lime, barytes, strontian, and magnesia.

Crystallized carbonate of lime may be known by its lightness, and by being found in rhomboids. Its specific gravity is only 3.00, being the lightest of all the earthy salts.

[†] Carbonate of barytes was found native by Dr. Withering in 1783. It is not so scarce and dear as it was formerly; and, from its superior affinity, may become a most useful article in the arts. Carbonate of strontian is found native at Strontian in Scotland; carbonate of lime exists native in a variety of states in great abundance: the other carbonates are in general formed artificially.

[‡] Carbonate of lime is not soluble in water, unless the water itself be charged with carbonic acid: it is by this means that Nature effects a solution of calcareous masses, to form stalactites, and other beautiful incrustations. See page 163.

[§] The only phosphoric salt which is found native is the apatite, or phosphate of lime, which occurs in abundance in many parts of the world.

high temperature; are soluble in nitric acid without effervescence; and are precipitable from their solutions by lime-water.

Which are the chief phosphoric salts?

The phosphates of lime [||], of soda [¶], and of

[||] Phosphate of lime is found in bones, milk, and some other animal matters. See Note, page 172. It is white, tasteless, and insoluble in water. Entire mountains in Spain are formed of this salt. It is composed of phosphoric acid 41 parts, lime 59. It is prescribed by the French physicians as a specific in the rachitis, to diminish the effects of acids which soften the bones. Fourcroy, vol. iii. 346. See Bonhomme's paper on this subject in Annales de Chimie, tome xvii.: the cases which he adduces are extremely curious.

Phosphate of lime exists also in the farina of wheat. La Grange remarks, that a person who eats a pound of farina a day will swallow 3 pounds 6 ounces 4 drams and 44 grains of phosphate of lime in the year. It is a curious fact, that the grain of wheat should contain *phosphate* of lime, while the straw, which was *not* intended for our food, should contain *carbonate* of lime only.

It is remarkable, that, though phosphate of lime is always found in the urine of adults, this salt is not evacuated by infants. The rapid formation of the bones in the first periods of life requires that there should be no waste of any of the phosphoric salts; and Nature, ever provident, has provided accordingly.

[¶] Phosphate of soda is formed artificially. It was first made and recommended by Dr. Pearson. This salt is used in medicine as a cathartic, and is much pleasanter than either Glauber or Rochelle salts. It forms very distinct small crystals; and is used by some manufacturers as a flux, instead of borax.

ammonia[*], and the phosphate of soda and ammonia, formerly called microcosmic salt[†].

What are the generic characteristics of the PHOSPHITES[‡]?

The phosphites yield a phosphorescent flame when heated; and in a strong fire give out a portion of phosphorus, by which they become converted into phosphates[§]. They are fusible by a violent heat into glass.

Endeavour to enumerate the principal phosphites.

The chief of them are; the phosphites of lime, of barytes, of potass, of soda, and of ammonia[‖].

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[*] Phosphate of ammonia is found in urine, and is also prepared by art to be used as an ingredient in making pastes, to imitate precious stones. It is one of the best fluxes for experiments with the blow-pipe.

[†] Phosphate of soda and ammonia is found in human urine, from whence it may be procured by evaporation in the state of a triple salt.

[‡] None of the phosphites have been found in nature; they are all formed artificially, by saturating the different bases with phosphorous acid, or by means of double decomposition. None of them have yet been brought into use. Fourcroy distinguishes eleven species of the earthy and alkaline phosphites.

[§] The affusion of nitric or oxygenized muriatic acid will also convert these salts to phosphates.

[‖] Phosphite of ammonia exhibits several curious appearances when treated with caloric. For all the particulars, consult Fourcroy, vol. iii. 405. If heated on charcoal by means of a blow-pipe, it boils and loses its water of crystallization; it then becomes surrounded with a phosphorescent light, and

What are the generic characteristics of the FLUATES?

The fluates are weak salts, yielding, by means of concentrated sulphuric acid, a vapour which corrodes glass, and which, when condensed in water, forms liquid fluoric acid. They are not decomposable by mere heat, nor altered by combustibles*.

Which are the chief fluoric salts?

Fluate of lime †, fluate of soda, fluate of

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bubbles of phosphuretted hydrogen gas are emitted, which burn in the air with a lively flame, and form a fine coronet of phosphoric acid vapour.

* The fluates were first made known by Scheele in 1771. Some of them phosphoresce when heated.

† Ten varieties of fluate of lime have been found. They are of different colours, owing to the different degrees of oxidizement of the iron which they contain. If any of these coloured fluates be pulverized, and then heated on a shovel, they will emit a violet phosphoric light, the cause of which is not known. We have no means of dissolving fluate of lime in water: but Nature dissolves it by some unknown process; for it is found in crystals, combined with its water of crystallization. This crystalline substance is known by the names of Derbyshire spar and Blue John. It is of various colours, and bears an excellent polish: hence it is used in making ornamental vases, &c. Where there are flaws or cracks in the mineral, I am told the workmen have an ingenious method of filling them up with lead ore, which they execute so well, that it cannot be discovered but by very close examination. Such specimens of the mineral as are not fit for ornamental work, will answer very well for the production of fluoric acid. The refuse of these

ammonia*, fluate of alumine, and fluate of silex.

What are the generic characters of the BORATES?

The borates are all fusible into glass; and, with most of the metallic oxides, form glass of different colours†. Concentrated solutions of some of the borates, especially that of soda, afford, by the strong acids, scaly crystals of boracic acid.

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mines, is, I understand, collected in Derbyshire to be used as a flux in the reduction of certain metallic ores.

According to some modern experiments, fluoric acid forms a part of the human teeth; it is probably combined with lime. It may be conjectured that this was a contrivance of Nature, to give more durability to these important organs than they would have had by phosphate of lime only.

Fluate of lime is very abundant in nature. It is often found in beautiful octahedral or cubical crystals. The other fluates are factitious salts, except fluate of alumine, which has lately been found in Greenland, in a mineral called the *chrysolite of Greenland*. It contains also a large portion of soda.

* Fluate of ammonia is a very delicate test of lime. This was first recommended by Scheele.

† It is from the property which these salts possess of fusing mineral substances and metallic oxides, that they are used by braziers, tin-men, &c. We employ sub-borate of soda to fuse such stones as cannot be brought into fusion by the alkalies. In analysing stones and minerals, the great art is to bring them into solution. When this is effected, their component parts may be readily separated by the different chemical re-agents. Mr. Chenevix was unable to liquefy corundum by any means till he made use of borate of soda.

Can you enumerate the boracic salts?

The principal are; the borates of lime‡, of magnesia§, of potass, and the sub-borate of soda‖.

What is the distinguishing characteristic of the ARSENIATES?

When heated with charcoal they are decomposed, and arsenic sublimes, which is known by its alliaceous or garlic smell.

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‡ What is called cubic quartz is a borate of lime and magnesia.

§ Borate of magnesia has also been found near Lunenburgh. The other borates are factitious salts.

‖ This salt, which is the common borax of commerce, is called sub-borate, because it contains an excess of soda. According to Bergman, it requires half its weight of boracic acid to bring it to the state of a neutral salt. It is generally brought from the East Indies in a state of impurity. The article is then called *tincal*. Borax has also been found near Lunenburgh, in the duchy of Brunswick, in a mountain of gypsum.

Borax is likewise found at the bottom of pools of stagnant water, in the kingdom of Thibet. A particular account of the management of the natives in procuring it may be seen in Dr. Anderson's Bee, vol. xvii. 22.

Boracic acid is found dissolved in several lakes of Tuscany. In the waters of the lake Cherchiago, near Monterotondo, in the province of Sienna, this acid exists in sufficient abundance to be advantageously converted into borax, by soda. Fabroni, a chemist of eminence in Florence, asserts that this acid is a modification of the muriatic, and that it may be totally formed by means of the latter acid.

Which are the chief salts formed with arsenic acid?

The arseniates of lime, of barytes, of magnesia, of potass*, of soda, and of ammonia†.

What are the characters of the TUNGSTATES?

The salts called tungstates are combinations of the yellow acid of tungsten with the alkalies and earths. Most of them have a metallic and caustic taste‡.

Which are the principal salts formed with the tungstic acid?

The tungstates of lime§, of magnesia, of potass, of soda, and of ammonia.

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[*] Arseniate of potass may be formed by detonating in a crucible a mixture of nitrate of potass and arsenious acid. This salt does not crystallize, but if heated it melts into a white glass.

Scheele discovered that whenever tin is dissolved in arsenic acid, hydrogen gas is evolved, holding a portion of arsenic in solution. If ignited at the end of a metallic tube, this gas burns with a peculiar kind of lambent white flame.

[†] Most of the arseniates are formed artificially; few of them are used in the arts; though some of them have been employed in calico-printing. They were first formed by Macquer. Fourcroy is of opinion that the nature of these salts ought to be further investigated. He imagines that the arsenic acid in some of its combinations, will at some future day become of great utility in manufactures.

[‡] We owe to Scheele the discovery of the salts of tungsten. They have lately been described with great accuracy by Vauquelin, in Journal des Mines, No. 19.

[§] Tungstate of lime, which is found native, is well known to mineralogists: the other tungstates are formed by art.

What are the generic characteristics of the ACETATES?

The acetates are all very soluble in water; are decomposed by the action of heat; and afford acetic acid when distilled with sulphuric acid.

Which are the chief acetic salts?

We have the acetates of barytes[||], of potass[¶], of soda, of lime[*], of ammonia[†], and of magnesia.

What are the generic characteristics of the OXALATES?

The oxalates are decomposable by a red heat; lime-water precipitates a white powder from their neutral solutions; which powder, after being exposed to a red heat, is soluble in acetic acid.

[||] Acetate of barytes has been employed as a chemical test. It is the most delicate test that can possibly be for sulphuric acid, and is peculiarly proper for the discovery of sulphuric acid in vinegar that has been sophisticated by this addition. This salt is, however, decomposable by the alkaline carbonates.

[¶] The acetates of potass, of soda, and of ammonia, have long been known and prepared for medicinal use: the other earthy and alkaline acetates have not yet come into use, except the acetate of alumine, which is employed by calico-printers as a mordant. Acetate of potass was known and described by Raymond Lully.

[*] According to Pliny, acetate of lime was used by the ancients in surgery. Lib. xxxvi. cap. 24.

[†] A solution of this salt has been used from a very early date in pharmacy, under the name of *Mindererus's spirit.* It is not crystallizable; for if evaporated with that intention it volatilizes entirely.

The insoluble oxalates are rendered soluble by an excess of the more powerful acids*.

Can you enumerate the principal oxalic salts?

Oxalate of lime†, of barytes, of potass‡, of soda, and of ammonia.

What are the generic characteristics of the TARTRATES?

When the tartrates are exposed to a red heat, the acid is decomposed, and the base remains. The earthy tartrates are less soluble than the alkaline, but all are capable of combining with another base, and forming triple salts.

Can you enumerate the principal tartaric salts?

The principal are; the tartrates of lime§, of strontian, and of potass; and the tartrates of potass and soda, and of potass and ammonia.

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* This genus of salts was first described by Bergman in his dissertation on oxalic acid.

† Oxalate of lime is one of the compounds most frequently found in human calculi. Vauquelin, Annales de Chimie.

‡ Oxalate of potass and oxalate of ammonia are both very useful tests of lime. These tests never fail to discover the presence of lime, except that earth be supersaturated with muriatic or nitric acid—in either case it is necessary to take up the excess of acid by the addition of caustic ammonia before using the test.

Oxalate of potass is prepared in England in considerable quantities for the calico-printers. It is found ready formed in the juice of *wood-sorrel*, in the state of a superoxalate. The other oxalates are not yet in use.

§ Tartrate of lime is found in the tartar of commerce; and it is also formed by art, by adding lime or its carbonate to a

What are the generic characteristics of the CITRATES?

The citrates are decomposed by the strong mineral acids; they yield traces of acetic acid when distilled; and the oxalic and tartaric acids decompose them.

Which are the principal citrates?

The citrates of lime, of barytes, of potass§, of soda, and of ammonia‖.

What are the generic characteristics of the CAMPHORATES?

The camphorates have generally a bitterish

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boiling solution of cream of tartar. This latter salt is merely the common tartar, or argol, purified, which adheres to the inside of wine casks, and is brought in large quantities from the wine countries. There is a considerable demand for it by the dyers and other manufacturers; and both in the crude and refined state there is an excess of acid, therefore they are properly called *super*-tartrates of potass. Tartrate of potass and soda is what is usually called Rochelle salt, or sel de Seignette; it is formed artificially by adding soda in crystals to a solution of cream of tartar, till the excess of acid is saturated. A neutral tartrate of potass is also formed in our laboratories, called soluble tartar. The other tartrates are made without any view to their use in the arts.

§ The citrates are all formed artificially. Citrate of potass is used much in medicine, and is usually called the *saline draught.* The other citrates are not yet found to be of any use.

‖ The affinities of the citric acid are in the following order: barytes, lime, potass, soda, strontian, magnesia, ammonia and alumine.

taste; they are decomposable by heat, and burn with a blue flame.

Which are the principal camphorates?

The camphorates of lime, of potass, of soda, of barytes, of ammonia, of alumine, and of magnesia[*].

What are the generic characters of the SUBERATES?

The several suberates differ so much in their properties, that it would be difficult to characterize the genius otherwise than by saying that they generally possess a bitter taste, and are decomposable by heat.

Which are the principal suberates?

Suberate of barytes, of potass, of lime, and of ammonia[†].

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[*] Camphoric acid saturated with potass forms crystals in regular hexagons; with soda, irregular crystals; with ammonia it forms needle-formed crystals; and with magnesia, a white pulverulent salt.

These salts, which have not been applied to any useful purpose, are also all formed artificially. For an account of their properties, consult Fourcroy, or Thomson's System of Chemistry.

[†] The suberates, which are all factitious, are more or less soluble: some readily crystallize, others with difficulty; there are some which remain pulverulent, whilst others are deliquescent. The mineral acids decompose these salts, and precipitate from their solutions the suberic acid which separates in the crystallized form. None of these salts are yet come into any use.

What are the generic characters of the PRUSSIATES?

The prussiates are so variable in their characters, and so easily altered, that little attention has been paid to their real nature. In the alkaline prussiates the acid is united so feebly as not to destroy their alkaline properties. The triple prussiates are those most known, and most useful.

Which are the principal prussiates?

The prussiates of potass, and of lime, and the triple prussiates of potass, soda, lime, or ammonia, with iron; that of potass was formerly called prussian alkali ‡.

How are these different salts known from each other?

They are known by the peculiar figure of their

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‡ The prussiates are all made by art, but the class is very interesting. There are four different prussiates of iron, which differ from each other in consequence of the different degrees of oxidizement of the iron. Prussiate of lime and iron, or prussiate of potass and iron, are used as tests to ascertain the presence of metals held in solution. The latter, known by the name of *prussian alkali,* is the best combination of the prussic acid for detecting the existence of iron. It is of the utmost importance to us as a re-agent, from its property of forming insoluble compounds with metallic oxides. By this property it occasions precipitates in metallic solutions, which vary in colour according to the kind of metal precipitated. For the best method of preparing this test, consult Dr. Thomson, vol. ii. 515.

crystals*, by their taste, by their fusibility, and other distinctive or *specific* characters.

What is meant by the figure of their crystals?

There is a great variety in the form of crystallized salts; and each salt preserves its own peculiar form †: thus common culinary salt generally crystallizes in small cubes, and sulphate of soda in six-sided prisms.

How is the crystallization of salts effected ‡?

When a certain portion of the water of solu-

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* The chief work on this subject is, I believe, that of the Abbé Hauy, to which I refer the student. See Additional Notes, No. 15.

† When, either by the diminution of the quantity of the liquid, or the reduction of the temperature, the force of cohesion causes a separation of a portion of the dissolved substance, in almost all cases the parts which are separated form a regular arrangement; owing to the relation between their figure and reciprocal affinity.—Hence those crystals which Nature offers in such variety, and which are produced in so great a number of chemical combinations.

The plates which continue to be added (either because the crystal acts on the dissolved substance, or because the cause of the separation continues to exist in the liquid) are composed of moleculæ similar to the first, and continue to augment the bulk of the crystal, preserving its first form; nevertheless, this increase may be determined to one face in preference to another, according to the position of the crystal and the circumstances in which the solution is found. See Berthollet's Chemical Statics.

‡ Crystallization is effected by means of water or caloric,

tion is evaporated, and the remainder left in a proper temperature at rest, the salts will shoot into crystals §, and will be found dispersed through the mother water at the bottom and at the sides of the vessel ||.

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one of which is necessary to keep the parts of the substance in a state of minute division. In order that regular crystallization may take place, it is necessary that the fluid, whether water or caloric, or both, should be subtracted *gradually*. This gives an opportunity for the parts of the substance to unite regularly, according to their several attractions, and to produce regular crystals, such as Nature furnishes; whereas, a sudden abstraction of the fluid causes the particles often to unite in a shapeless mass.

Sir Isaac Newton seems to have had a very clear idea of the cause of crystallization. "When," says he, "a liquor saturated with a salt is evaporated to a pellicle, and sufficiently cooled, the salt falls in regular crystals. Before being collected, the saline particles floated in the liquor, equally distant from each other; they acted therefore mutually on each other, with a force which was equal at equal distances, and unequal at unequal distances; so, in virtue of this force, they must arrange themselves in an uniform manner." Optics, book iii.

§ The free access of air has considerable influence on this process. For if a saturated solution of any salt be put into a vessel boiling hot, and then excluded from the air, it will cool without crystallizing; but if the air be afterwards admitted it will crystallize immediately. See Experiment, No. 17.

|| In large laboratories the salts of commerce are prepared by evaporation and cooling, but it is necessary to vary the process for almost every different kind of salt. So much nicety is necessary, that many manufacturers are much perplexed by

What is meant by mother water?

Mother water is the liquor which remains after a salt has combined with its portion of water necessary for crystallization. By repeating the evaporation and cooling* mother waters generally afford fresh portions of salt.

What is the cause of the crystallization of salts?

The crystallization of salts is owing to their forming a chemical combination with a portion of the water in which they are dissolved†; in

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this part of their business, till they have established each process on the basis of experiment.

Some valuable directions for crystallizing salts may be found in Dr. Campbell's paper, in Nicholson's Journal, 8vo. vol. ii. 117. See also Le Blanc's directions in the same work, vol. i. 191. also the Encyclopædia Britannica, vol. iv. 443.

* For boiling down saline liquors in the large way, leaden boilers, or boilers made with plates of sheet iron rivetted together, are the most proper. The plates should not, according to my experience, be more than nine or ten inches wide, made of the best tough *hammered* iron, three-eighths of an inch thick in the middle, and one-fourth of an inch thick at their edges. If made with plates wider or thinner, the bottom will warp, and soon become useless. Common rolled iron will be sufficient for the sides. These pans are manufactured best in Lancashire and Cheshire, where there is a great demand for them for the salt wiches. Boilers of *cast* iron would crack by the adhesion of the salt to them.

† It must not be imagined that all crystallization is owing to solution in water. Melted sulphur always crystallizes on

which combination the water parts with its caloric of fluidity and takes a solid form.

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cooling, which is the case with many substances that have endured a strong heat. Many of the metals crystallize in this way, particularly grain tin. Nothing can exemplify this kind of crystallization better than muriate of lead, commonly called patent yellow. It affords beautiful and regular crystals on cooling. See Additional Notes, No. 23. If glass be kept in a red heat for a long time and cooled gradually—instead of being the transparent body we generally see it—it will crystallize like metals. Starch is another instance of what may be called *dry* crystallization; and probably, in all these instances, it is owing to the shrinking of the substances by the loss of caloric. Dr. Garnet accounts for the origin of basaltes in this way (See his Tour to the Western Isles). The Giants' Causeway, in the county of Antrim in Ireland, is a most stupendous natural curiosity of this kind. It is formed of perpendicular pillars of basaltes, which stand in contact with each other. The pillars are irregular prisms of various forms, from three to nine sides; but they are principally hexagons. The appearance of the whole is as neat as it is magnificent. The columns at Fairhead are 250 feet high, arranged in the utmost regularity and order; and from the base to the level of the sea there is a precipitous declivity of at least 300 feet, making together a perpendicular height of 550 feet. For a further account of this most astonishing natural curiosity, I refer the reader to " The honourable Mrs. Murray's Companion to the Western Highlands of Scotland," and to " Dr. Richardson's Observations," in Nicholson's Journal, vol. v. 4to. 321. See also Additional Notes, No. 14.

Basalt is now used in the manufacture of glass bottles. When calcined and pulverized it imparts to mortar the property of hardening under water.

What is the water called which combines with salts during their crystallization?

It is called the water of crystallization*.

What quantity of water do salts combine with during their crystallization?

The quantity of water varies very much in different salts; for though some salts take up very little water, others combine with more than their own weight, which is the case with alum, carbonate of soda†, and some others.

Are salts as unalterable in their appearances as they are in their chemical properties?

No: *crystallized* salts are liable to changes in their appearance by exposure to atmospheric

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* This water *solidifies* as the salt crystallizes, and becomes itself a part of the salt. When abstracted from salts, it is found to be as pure as distilled water.

† Take a portion of sulphate of soda (Glauber's salt) and dry it over a common fire, which will reduce it to less than half its weight. Dissolve this dried salt in three times its weight of boiling water, set the liquor aside, and, when cold, beautiful crystals resembling the original crystals will be found in the liquor. By an attentive examination of the liquor, the crystals may be seen to form as the liquor cools. This is a cheap and easy experiment, and may be exhibited to the pupil as an example of crystallization in general.

air[‡]. Thus some salts deliquesce, and others effloresce, so as to lose their crystalline form entirely by such exposure.

What is meant by the DELIQUESCENCE *of a salt?*

Some salts have so great an affinity for water, that they absorb it with avidity from the atmosphere. Such salts thereby become moist or liquid, and are said to deliquesce, by exposure to atmospheric air[§].

What is meant by the EFFLORESCENCE *of a salt?*

Some salts, having less affinity for water than

[‡] A Table of the Action of Atmospheric Air on Salts.

Potass	Deliquesces	Nitrate of potass	None
Soda	Sub-deliquesces	—— soda	Sub-deliquesces
Carbonate of potass	If in crystals, none	—— ammonia	Agglutinates
—— soda	Effloresces	—— barytes	Slightly efflorescent
—— ammonia	None	—— lime	Deliquesces
—— lime	None	—— magnesia	Deliquesces
—— magnesia	None	Muriate of potass	None
Sulphate of potass	None	—— soda	None
—— soda	Effloresces	—— lime	Deliquesces
—— lime	None	—— ammonia	Sub-deliquesces
—— ammonia	Sub-deliquesces	—— barytes	None
—— magnesia	Effloresces	—— magnesia	Deliquesces.

[§] Some deliquescent salts have so little force of cohesion, that the action of water, however small the quantity, is sufficient to prevent their crystallization; but even such salts may be crystallized by the addition of alcohol, for which the water atmospheric air* has, lose their water of crystallization by exposure, and readily fall into powder; such salts are said to effloresce. Carbonate and sulphate of soda are good examples of this property.

Are salts capable of any other changes besides efflorescence and deliquescence?

Yes: salts have the properties of solubility † and fusibility.

What is meant by the SOLUBILITY *of a salt?*

It is their capacity to unite with, and remain

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has a greater affinity than it has for the salts. Whenever alcohol therefore is added to such saline solutions, part of the water is taken up by the alcohol, and crystallization takes place. This shows that these salts do possess in themselves an active cohesion of parts.

* Muriate of barytes, muriate of soda, and some other salts seem to have exactly the same affinity for water that atmospheric air has. Such salts neither effloresce nor deliquesce by any exposure to the atmosphere.

† Table of the Comparative Solubility of some of the Common Salts.

SALTS.	Solubility in 100 parts of water.		SALTS.	Solubility in 100 parts of water.	
	at 60°.	at 212°.		at 60°.	at 212°.
Sulphate of potass	6.25	20.	Muriate of potass	33.	
———— soda	37.	125.	———— soda	35.42	36.16
———— lime	0.2	0.22	———— lime	200.	
———— ammonia	50.	100.	———— ammonia	33.	
———— magnesia	100.	133.	Carbonate of potass	25.	83.33
Nitrate of potass	14.25	100.	———— soda	50.	100.
———— soda	33.	100.	———— ammonia	50.	100.

suspended in water; but the different salts possess different degrees of solubility[‡], requiring more or less of this fluid for their solution.

What is meant by the FUSIBILITY *of a salt?*

Salts have not only the property of dissolving in water, but will melt by exposure to great heat. The different salts require different degrees of heat to put them in a state of fusion[§].

[‡] We generally denominate all salts as insoluble, which require for solution more than 1000 times their weight of water. The most general rule for judging of the *solubility* of a salt is by its taste. Those salts which have the most taste are generally the most soluble in water.

This difference in the solubility of salts is of great use in separating them from each other. The refiners of saltpetre operate entirely on this principle; for the rough petre, as it is called, is always contaminated with a portion of muriate of soda and other salts. In order to separate them they dissolve the whole in water, and then by boiling the solution to evaporate a part of the water, the muriate of soda, &c. falls down, while the saltpetre is held in solution. When the greatest part of these salts is thus separated, the remaining liquor is suffered to cool, and the nitrate of potass is obtained in crystals. See Additional Notes, No. 22.

Most salts dissolve more copiously in hot than in cold water. Muriate of soda, or sea-salt, is almost the only exception to this general law. Was this deviation of Nature contrived in reference to the waters of the ocean?

[§] Tables of the fusibility of different salts have not yet been formed; but with the aid of Wedgwood's pyrometer it would be no very difficult task to ascertain the degree of fusibility of each. The relative fusibility of several of them is already known; for instance, it has been ascertained that sulphate of

Have the different salts any action upon each other?

Yes: we have many instances of salts mutually decomposing each other.

What takes place in these decompositions?

When such salts are mixed in solution, the acid of the *first*, having more affinity for the base of the *second* than for its own base, unites itself to it, while the acid of the second combines with the base of the first; so that two new salts are produced, differing in appearance, and possessing properties different to those of the original salts.

What is the cause of this effect?

It is occasioned by chemical attraction, and the operation itself is called double decomposition, or the effect of compound affinities*.

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potass requires a much more intense heat to put it in a state of fusion than sulphate of soda; whereas nitrate and muriate of soda melt as soon as they become red. Some salts acquire fusibility by the loss of a part of their acid. Thus caustic alkalies are incomparably more fusible than carbonate of potass, or soda. In decomposing sulphuric salts in the large way, I have often hastened the process by the addition of a few shovels full of quick-lime; but whenever this is had recourse to, the utmost caution is necessary in the management of the fire; as the alkali becomes, by this means, more liable to vaporization.

* Those who wish to investigate this subject may consult Bergman's treatise on "Elective Attractions," or Fourcroy's last System of Chemical Knowledge. See Nicholson's Translation of the latter work, vol. iv. 173.

What use is made of these decompositions?

By these means many valuable salts are procured for the use of the chemist and the manufacturer, which can be formed in no other way[†].

What knowledge have we attained respecting the native *salts?*

Many of the salts are found native; and since the science of mineralogy has been so much cultivated, great attention has been paid to these natural productions[‡].

What salts are furnished by nature in the greatest abundance?

The carbonates, the sulphates and the muriates, are most abundant; but some of the nitrates, borates, &c., are also found native.

Which of the carbonates have been found native?

Of carbonate of lime[§] there are immense

[†] The following are some of those useful salts which are not found native, but are formed entirely by art:—sulphate of ammonia, nitrate and muriate of barytes, nitrate of ammonia, oxygenized muriate of potass, phosphate of soda, phosphate of ammonia, &c.

[‡] Fourcroy is of opinion, that in proportion as fossils are examined, all the salts which art can fabricate will be found native.

[§] Chalk, limestone, and marble are all included in the term, carbonate of lime. The late experiments of Sir James Hall have thrown great light on the formation of these natural productions. See Edinburgh Phil. Trans. vol. vi.

Carbonate of lime is found also in a crystallized state, called mountains in most parts of the world; carbonate of barytes has been found in Lancashire and elsewhere; carbonate of strontian, at Strontian in Scotland; carbonate of soda, in the natron beds of Egypt, and in the East Indies; and carbonate of potass, as well as the carbonate of soda, has been discovered in some spring waters.

What sulphuric salts are found native?

Sulphate of soda is found in sea-water and in salt springs*; sulphate of magnesia, in spring water†; sulphate of alumine, in abundance at

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calcareous spar. It has never yet been crystallized by art. This process of Nature, for ought we know, may require many ages to effect.

[*] According to the analysis of M. Lavoisier, the proportion of sulphate of soda in sea-water is very small. Some time ago Mr. Hume analysed the famous mineral-water at Godstone in Surry, and found it to contain 160 grains of sulphate of soda per gallon.

[†] Sulphate of magnesia and sulphate of lime are both very common in our spring waters; the last salt and supercarbonate of lime are the chief causes of what we call *hard* waters, which are very unwholesome and unfit for washing. When soap is used with these waters a double decomposition takes place; the sulphuric acid of the selenite unites with the alkali of the soap and forms sulphate of potass, or sulphate of soda, which remains in solution, while the magnesia or lime unites with the tallow and forms an insoluble compound which swims upon the surface of the water like curds. In this way hard waters require much more soap for any given purpose than rain water, or waters which do not contain these earthy salts. Such waters are also unfit for boiling any esculent vegetable; but they may

Whitby; sulphate of barytes, in Derbyshire and other parts of the world; sulphate of strontian, in the neighbourhood of Bristol; and sulphate of lime is an abundant mineral in the vicinity of Paris and in several of the counties of England ‡.

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be rendered soft by adding to them a very little carbonate of soda, or carbonate of potass, 24 hours previous to their use. By this addition, a double decomposition will be effected, and the carbonate of lime, a very insoluble salt, precipitated.

The property which sulphate of lime has of setting into a compact mass when mixed with water was well known to the ancients.

Herodotus informs us of a curious method by which the inhabitants of Ethiopia preserved the remembrance of their deceased relatives. They had the custom, he says, of drying the body in the sun, then covering it with a paste of gypsum, and afterwards painting the portrait of the deceased upon the plaster covering that encrusted the real body.

‡ Sulphate of lime is gotten in great abundance at Chelaston near Derby, and at Beacon Hill near Newark. At the former place 800 tons are annually raised; it is sold at 5*s.* per ton on the spot. The price at Gainsbro' is 8*s.* per ton. This mineral is much used in Derbyshire for making the floors of cheese-chambers, store-rooms, granaries, &c. They burn the gypsum, grind it to powder, and then mix it with water. In this state it is laid upon the floors about 2½ inches thick, and when dry is a smooth and durable flooring. The whole expense is generally less than 1*s.* 6*d.* per square yard. Gypsum is also found in most of the cliffs of the Severn, especially at the Old Passage near Bristol. For the London market, perhaps, it might be gotten cheapest from the Isle of Sheppy, where it may be had in abundance.

What native MURIATIC *salts are there?*

Muriate of lime and muriate of magnesia are found in abundance in sea-water*; muriate of ammonia appears in the neighbourhood of volcanos; and muriate of soda not only exists in immense quantities in the ocean †, but vast moun-

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* The magnesia of commerce is generally procured from this source. It is prepared in great quantities in the island of Guernsey, and elsewhere.

† In the south of France large trenches are cut near the sea, which fill with sea-water at high tide; the water being confined there by flood-gates, the sun evaporates it and leaves the salt in the trenches, from whence it is laid up to dry for use. Nicholas has published a long memoir on this manufacture of salt, in Ann. de Chimie, tom. xx. 78—188.

Dr. Shaw gives an account of salt-works on the coast of Syria, where the rocks on the sea-shore have been hollowed into salt-pans 2 or 3 yards long. By continually throwing in sea-water, as the aqueous part evaporates, a large quantity of salt gradually forms at the bottom. Travels in Barbary, last edition, page 344.

The ocean contains from $\frac{1}{25}$th to about $\frac{1}{35}$th of its weight of salt. On account of the cheapness of fuel at Newcastle, salt is procured there by the evaporation of sea-water. They evaporate 30 or 40 tons of water to procure one ton of salt.

At some places in Cheshire, they draw the brine from the salt-pits and saturate it with rock salt previous to its being boiled down. The port of Liverpool is supplied from these wiches, where it is sold for 1*s.* per cwt., for exportation. According to lord Dundonald, 100 tons of a saturated solution of rock salt in sea-water contain 23 tons of salt.

tains in different parts of the world are entirely formed of this salt[‡].

Which of the NITRIC *salts are found native?*

Nitrate of potass is found in various parts of the world; nitrate of magnesia sometimes occurs

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In Sweden they freeze the sea-water, throw away the ice, and boil down the remainder to salt.

In the landgravate of Thuringia in Saxony a new method has been adopted in the manufacture of salt. A number of vessels of wood are placed firm upon posts 6 feet from the ground, which may be covered or uncovered in an instant by a moveable roof, accordingly as the weather is dry or rainy. In this manner salt is obtained by the mere heat of the sun, and such salt is much purer than that which is procured by evaporation in boilers. Nicholson's Journal, 4to, vol. ii. 72.

[‡] The salt-mines near Cracow in Poland, which have been worked ever since the middle of the thirteenth century, contain an immense store of this salt. The excavations have been made with so much regularity and beauty, that these mines are visited by travellers as one of the greatest curiosities in the world. Eight hundred workmen are employed in them, who raise 168,000 quintals of salt annually. Through the enormous mass of salt, which presents to the eye no interruption in its saline texture, and at the depth of 450 feet, flows a stream of pure, fresh, and transparent water, which is received in large wooden vessels, where the workmen and horses of these subterranean regions quench their thirst. As it was impossible that this spring could filter through the salt, Nature, who buries her masterpieces in the bowels of the deepest mountains, has placed in this monstrous mass a stratum of clay sufficiently thick to allow the stream of water, destined to refresh the workmen, to pass through it in such a manner as to be pro-

in combination with that salt; and nitrate of lime is found in calcareous stones, and in mineral springs:—these are the only nitric salts that have been seen native in any large quantities.

Are any other of the salts found native?

Yes: vast rocks in Derbyshire and elsewhere are formed of fluate of lime*; borate of soda is found in a crystallized state in the kingdom of Thibet; and phosphate of lime, which is the basis of all animal bones, exists native in Hungary, and composes several entire mountains in Spain.

How do you imagine that these immense masses of salts have been formed by nature?

The vast mountains of salts which occur in various parts of the earth were probably formed in very remote ages, and by processes of which we can form no idea. It may be supposed that these changes have been slow and gradual, as several of the native salts exhibit marks of regu-

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tected from the action of the salt, of which a very small quantity would injure its salubrity. See an interesting account of these mines in vol. x. of the Phil. Mag.

* This crystallized substance is used for vases and other ornamental work, some of it being extremely beautiful. It obtained the name of *fluor* spar, on account of its being readily fused. It has also been called *vitreous* spar, because when fused it has the appearance of glass. It is generally found

larity and beauty in their crystallization, which cannot be imitated by art[†].

Have geologists attempted to account for the production of the immense quantities and varieties of salts found in different states in various parts of the earth?

The cause[‡] of this order of things can only be

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in very regular cubical crystals, and of various colours. See page 275.

[†] In order to account for these productions of nature, various *theories* of the world have been formed by philosophers in different periods. Some of these have had many supporters. Thus we have had the theories of Burnet, Woodward, Whiston, Buffon, Whitehurst, La Place, and other noted geologists.

The theories which divide the opinions of the present day, are those of Hutton and Werner. The former supposes the agency of fire, and is called the Plutonian system; the latter, which attributes all the present appearances of the globe to the effect of water, is called the Neptunian system. The reader may become acquainted with the arguments which have been adduced in support of both these theories, by means of the following works, which cannot fail to prove extremely interesting to those who are fond of such inquiries: "Playfair's Illustration of the Huttonian Theory of the Earth," 8vo, 1802; And "An Examination of Playfair, by Mr. Murray of Edinburgh."

[‡] We have abundant reason to believe that nothing is fortuitous, but that every thing upon this fair world of ours is the effect of design; for every thing around us bears evident marks of the skill and beneficence of its Omnipotent Author. Is it not then reasonable to infer, that the formation of the whole of the globe entered into the divine plan; and that the constitution of the interior of its mountains resulted from the determi-

referred to the will of the Creator, who has seen fit, in the composition of many of the moun-

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nation of infinite wisdom, and must have important uses in some future period of the world?—

> "For lives the man whose universal eye
> Hath swept at once the unbounded scheme of things;
> Mark'd their dependence so, and firm accord,
> As with unfaultering accent to conclude
> That this availeth nought?"

It is probable indeed that the profusion of earthy and alkaline salts which occurs in the more elevated parts of the earth may, among other purposes, have been intended as magazines for the future renovation of the soils in their vicinities. They are in general of a nature to be washed down by the rains; and, by means of rivers, &c., are sometimes transported to considerable distances from their native beds. It is remarkable that these salts are generally found only in the *secondary* mountains, the materials of the *primitive* rocks being entirely different. These latter contain no remains of organic bodies whatever, and are composed, for the most part, only of five ingredients, viz., quartz, alumine, lime, magnesia, and iron; of which *quartz* is by far the most abundant and universal. Though a comparative softness has been given to the secondary mountains, which thus appear to have been designed for the successive production of alluvial depositions, the renovation of soils, &c., the rocks of granite, the pillars of the globe, are so extremely hard, that it is imagined they would resist the constant washing of the ocean for ages without any apparent diminution. Where they were originally fixed by the hand of Nature—

> "They still remain,
> Amid the flux of many thousand years,
> That oft has swept the toiling race of men,
> And all their laboured monuments away."

tainous parts of the globe, to prefer these compound substances to the simple and inert earths.

In this arrangement we perceive nothing like a fortuitous concourse of atoms, but, on the contrary, the same satisfactory marks of contrivance, which obtrude themselves upon us whenever we study the phænomena of the world, or behold any of the great operations of Nature.

CHAP. IX.

OF SIMPLE COMBUSTIBLES.

What is a SIMPLE *substance?*

Those bodies* which have never yet been decomposed nor formed by art are called simple substances.

How many simple substances are there?

The simple substances at present known do not amount to 50†; they are sometimes called *radicals.*

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* The most minute particles into which any substance can be divided *similar* to each other, and to the substance of which they are parts, are termed the *integrant* particles: thus the smallest atom of powdered marble is still marble; but if the lime, the carbon, the oxygen and the hydrogen of this marble be separated, we shall then have the *elementary* or constituent particles.

Suppose a little common salt were reduced to powder, even though it be ground as fine as could be effected by art, still every single particle, however minute, would consist of a particle of soda and a particle of muriatic acid; common salt being a *compound* body incapable of decomposition by mechanical means. But if we take a piece of sulphur, and pulverize that in the same way, every particle will be a homogeneous body, sulphur being one of the *simple* substances.

† If these substances were all capable of combining, the com-

Can you enumerate the simple substances?

All the simple substances that we are acquainted with are; light, caloric, oxygen, nitrogen, muriatic acid, nine earths, the four simple combustibles, and twenty-three metals‡.

Is it well ascertained that these are all simple substances?

It is possible that some of these bodies may be compound; but as no mode has yet been discovered of decompounding any of them, it will be more conducive to science, to consider them, for the present, as simple undecomposable bodies §.

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pounds formed by them would amount to a great many thousands; but many of them cannot be united to each other.

‡ If we omit the earths and alkalies (and there is some reason to suppose that these are compound bodies) most of the simple substances are combustible, or bear some relation to combustion, either as products or supporters of combustion. Light and caloric are evolved during combustion; oxygen is the principal agent of combustion; and hydrogen, nitrogen, sulphur, phosphorus, carbon, and the metals, are the subjects, or the true instruments, of this process.

§ It is curious that most of those substances which were thought by the old chemists to be the elements of all other bodies, are found by our improved methods of experiment to be more or less compounded; while, of those which were formerly ranked among the class of compounds, there are a great number that are really not decomposable, and can only be placed among the simple bodies. *Air*, *fire*, *water*, and *earth* were by the ancients called the elements of the globe: modern chemistry has demonstrated, that the three first of these are really compound bodies; and there is reason to believe that the

Having already examined the nature of all these substances, except the combustibles, we shall now enter upon the consideration of that class of bodies.—Endeavour, therefore, to enumerate the simple COMBUSTIBLES.

Besides the metals* there are four simple combustibles, viz. hydrogen, sulphur, phosphorus, and carbon.

Why are these substances called SIMPLE *combustibles?*

They are called *simple* because we have no proof that they are compounded: whereas oil, spirit of wine, wax, tallow, and other combustible bodies are well known to consist of two ingredients at the least†.

It will be necessary to examine each of these substances separately:—therefore, what is the nature of HYDROGEN‡?

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latter is also a compound. On the other hand, *sulphur, phosphorus, carbon,* and the *metals,* which we call simple substances, were supposed formerly to be compounds.

* The metals ought to have been included in this chapter with the other simple combustibles; but as several of their properties are so very different to the four substances now described, it was thought most advisable to treat of them separately.

† For the nature of the compound combustibles, consult the chapter on Combustion.

‡ Mr. Cavendish was the first person who examined hydrogen gas and pointed out its nature. Dr. Black then suggested the propriety of applying it to the inflation of air-balloons; and

Hydrogen is the basis of what has been generally called inflammable air§, and is one of the component parts of water‖; but it cannot be

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Mr. Cavallo was the first who put it in practice. This gas is about twelve times lighter than atmospheric air.

§ Like all other combustibles, hydrogen will not burn unless in contact with atmospheric air, or some substance that contains oxygen. If a portion of atmospheric air be mixed with this gas, and fire be applied, it will explode with violence. It is related of Pilatre de Rosier, that having mixed one part of common air with nine parts of hydrogen gas, and drawn the mixture into his lungs, it caught fire by accident as he respired it, and the whole of the gas exploded in his mouth and nearly deprived him of life. The shock was so violent, that at first he thought the whole of his teeth had been driven out, but fortunately he received no lasting injury whatever. Being myself engaged some time ago in a process in which a large quantity of hydrogen gas was evolved, and having incautiously brought a lighted candle too near the apparatus, the whole exploded with a tremendous crash; and several very large glass receivers were shattered into ten-thousand pieces, and driven in all directions about the laboratory. Such accidents should be noticed in every elementary chemical work, in order to inspire the young pupil with caution when operating on such substances.

‖ Hydrogen is the most inflammable substance we are acquainted with; that is, it combines with more oxygen than any other body, and occasions more heat by its combustion. It may be remarked that *oxygen* is mild when in the proportion of 22 per cent. in atmospheric air, and highly corrosive in the proportion of 70 per cent. in nitric acid; or even in that of 40 per cent. in sulphuric acid;—How is it, then, that it is found in the ratio of 85 per cent. in water, and that this compound, compared with the others, should be perfectly mild and innocent? Instances of a similar accommodation of the elementary exhibited in a separate state. We therefore know it only in combination with other substances, or in the gaseous form, that is, with caloric.

In what other compounds is hydrogen an ingredient?

Hydrogen gas may be combined with water, sulphur, phosphorus, or with carbon.

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substances have been adduced; and though we cannot comprehend the nature of their operation, we can perceive that the ultimate end of the Creator is the convenience and the happiness of his creatures. See pages 75, 76, and 224. Most oxidized substances, when taken internally, act perceptibl yon the system; yet water, the most oxidized of all others, has comparatively little influence, because its oxygen is so forcibly retained by the hydrogen. Had the affinity of hydrogen for oxygen been as feeble as that of nitrogen and oxygen, what is now the most salubrious beverage would have operated as a corrosive poison.

Berthollet has shown that at all temperatures there is a greater disposition in hydrogen than in carbon to combine with oxygen. Chemical Statics, vol. i. 244.

A mixture of oxygen and hydrogen gases produces the most powerful heat yet known. This may be shown by preparing a bladder full of each of these airs, and forcing some out of each into a common tube connected with both, and throwing a stream of the mixed gases on burning charcoal, or on any other substance in the act of combustion. These bladders should each be furnished with a small metallic pipe and stop-cock, and the tube connecting with both should have a very small orifice, in order that a regular stream of the commixed gas may be thrown on the burning substance. In performing this experiment all solid vessels should be discarded, for fear of an accident by explosion. When bladders are used no damage can arise, even if such an accident should happen.

What is the nature of the compound of hydrogen and water?

Water may be made, by pressure, to absorb a considerable portion of hydrogen gas. It is called hydrogenated water, and is said to be useful in medicine*.

What is the nature of the compound of hydrogen and sulphur?

Sulphur dissolved in this gas forms sulphuretted hydrogen gas†, which is a very fetid elastic fluid, somewhat heavier than atmospheric air, and soluble in water.

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* By *pressure,* water may be made to absorb near a third of its bulk of hydrogen gas. It is said that water, thus impregnated, is useful in inflammatory fevers and other complaints which require similar treatment.

† To obtain sulphuretted hydrogen gas, melt together in a crucible three parts by weight of iron filings and one of sulphur; reduce the mass to powder, and put it with a little water into a glass vessel with two mouths: lute one end of a crooked glass tube into one of these mouths, and let the extremity of the tube pass under a glass jar in a pneumatic trough, the jar being inverted and full of water. Then pour diluted muriatic acid through the other mouth of the vessel, which must immediately be closed up. Sulphuretted hydrogen gas will now be disengaged in abundance and flow into the glass jar, displacing the water.

According to Thenard, this gas is composed of 70 parts of sulphur and 30 of hydrogen. See Berthollet's paper on this gas in the Ann. de Chimie.

Water impregnated with sulphuretted hydrogen gas is of use to separate some metallic oxides when in solution. Thus, if it be added to a solution of acetate of lead, the lead will be precipitated of a deep brown colour.

What are the properties of sulphuretted hydrogen gas?

Sulphuretted hydrogen gas* possesses all the characters of an acid†: it combines with

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* This gas was long known by the name of *hepatic* gas, because the substances from which it was first obtained were called *hepars*, or *livers of sulphur*.

When this gas is set on fire in contact with oxygen gas, it burns with a pale blue flame without exploding. It will of itself extinguish burning bodies, and destroy animals which are made to inhale it.

Sulphuretted hydrogen gas is decomposed by atmospheric air. The oxygen of the atmosphere combines with the hydrogen and forms water, while the sulphur is precipitated. The sulphur which is found in the neighbourhood of mineral springs originates from this cause.

The fetid smell which arises from house-drains is owing in a great measure to a mixture of this gas with other putrid effluvia. As the diffusion of this noxious matter within our dwellings tends to produce disease and mortality, it cannot be too generally known that a cheap and simple apparatus has been contrived for carrying off the waste water, &c., of sinks, and which at the same time prevents the possibility of any air ever returning back into the house from thence, or from any drain which may be connected with it. It is known by the name of a *stink-trap*, and may be had of some of the ironmongers in London.

† As sulphuretted hydrogen gas is formed without oxygen, and yet possesses strong acid properties, it seems to overthrow the doctrine of Lavoisier, who asserted that oxygen was the only principle of acidity. Muriatic acid also has not yet been proved to contain oxygen.

Sulphuretted hydrogen is capable of combining with an additional portion of sulphur, forming a compound which may earths[‡], alkalies, and with several of the metallic oxides; and forms with them those substances called *hydrosulphurets*.

What are the properties of the hydrosulphurets?

The hydrosulphurets are soluble in water, and their solutions precipitate the metallic oxides from metallic solutions. Exposure to the air decomposes these hydrosulphurets when dissolved in water[§].

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be called super-sulphuretted hydrogen. For its properties see Murray's Chemistry, vol. ii. 451.

[‡] We have a mineral called swinestone, (or fetid carbonate of lime,) which is so fully impregnated with this compound, that, if it be merely rubbed, the disagreeable odour of sulphuretted hydrogen will be very perceptible.

[§] The waters of Harrowgate, Aix la Chapelle, and others of a similar nature, owe their medicinal properties to sulphuretted hydrogen gas and muriate of soda. The *salt of bitumen* of the Hindoos, which is almost the only article of Hindoo physic, and is sold in every village, is chiefly composed of muriate of soda and sulphuretted hydrogen. It is taken by these people for every complaint. Their farriers give it to the horses, and seem to understand the principle on which it acts; for when they have given a dose to the animal they always give him water to extricate the gas. Henderson on Hindoo Physic.

Secret correspondence has often been carried on by means of Harrowgate water. A letter written with a solution of acetate of lead is illegible; but if it be dipped in this water, the writing will appear, and shortly become almost black. Hydrogen has the property of reviving metallic oxides; hence ladies who have used metallic cosmetics, have become dark tawneys by bathing in these waters. See a note on Bismuth, chapter x.

What is the nature of the combination of hydrogen and phosphorus?

Hydrogen gas when combined with phosphorus forms *phosphuretted hydrogen gas*[*]. This gas has a fetid putrid smell, and takes fire whenever it comes in contact with atmospheric air[†].

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[*] Phosphuretted hydrogen gas may be formed by boiling a little phosphorus in a solution of pure potass. The water is decomposed thereby, and furnishes the hydrogen. The retort should be nearly filled with the solution, otherwise the gas will inflame.

This gas may be formed by introducing phosphorus into a glass jar full of hydrogen gas standing over mercury, and melting the phosphorus by means of a burning glass. It burns with great rapidity in common air, but in oxygen gas the combustion is extremely brilliant. If bubbles of this gas be made to pass up through water, they explode in succession as they reach the surface of the liquid, and a beautiful coronet of white smoke is formed, which rises slowly to the ceiling of the room. This gas is the most combustible substance known. Thomson, vol. i. 66.

Mr. Davy forms this gas by decomposing water with zinc and sulphuric acid, and adding to the mixture small pieces of phosphorus. But as some management is necessary in order to conduct the process successfully, I refer the reader to his paper in Nicholson's Journal for April 1802.

The facility with which phosphuretted hydrogen gas inflames is no doubt owing to the phosphorus being so minutely divided by the hydrogen.

[†] If bits of phosphorus be kept for some hours in hydrogen gas, *phosphorized hydrogen* gas is produced, having somewhat

What is the nature of the combination of hydrogen with carbon?

Carburetted hydrogen gas‡ is carbon dissolved in hydrogen; this has likewise been called heavy inflammable air§.

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of the smell of garlic. If bubbles of it are thrown up into oxygen gas, a brilliant blueish flame will immediately pervade the whole vessel. This slow combustion is owing to the gas containing *less phosphorus* than the *phosphuretted hydrogen* gas. It is this gas which is often seen hovering on the surface of burial grounds, known by the name of *will-o-the-wisp*.

"On distant swampy heath I see
A will-o-wisp——ah luckless he,
Who to next hamlet bends his way!
That glimpse will lead him far astray."

‡ In hot weather this gas is formed at the bottom of stagnant waters, and may readily be collected at their surface, by suspending a bottle of water over the pool, similar to the decanting of gases over a pneumatic trough, and stirring up the mud to disengage the carburetted hydrogen.

This gas generally contains a portion of carbonic acid mixed with it. Both these aëriform fluids are produced by the decomposition of water by putrid animal and vegetable matter. Such decompositions take place chiefly when the sun shines upon these waters, caloric being necessary to all gaseous compounds.

Carburetted hydrogen may be formed artificially by exposing charcoal in glass vessels filled with hydrogen gas to the rays of the sun. It is invisible, elastic, and inflammable. The proportions of carbon and hydrogen vary according to the processes by which the gas is obtained.

§ This gas is procured from pit-coal by dry distillation for the purpose of forming the thermo-lamp, and is now proposed to

What is the origin of SULPHUR?

Sulphur is found in most parts of the world* combined with metals, from which it is procured by roasting; it also flows from volcanos; it is sublimed from the sulphureous grounds in Italy,

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be employed for lighting the public streets, light-houses on the sea coasts, mines, manufactories, &c. See page 17. One pound of coal yields about 24 gallons of this inflammable gas, and the remainder serves for fuel, it being excellent coak. Its combustible property, and that it serves for the purposes of light and heat, were discovered about 70 years ago by the Rev. Dr. John Clayton. See Mr. Hume's letter in Nicholson's Journal, vol. xvi. p. 170. For an account of its employment in the support of a popular superstition see page 204.

All oils, resins, gums, wax, sugar, and numberless other inflammable substances, are composed of hydrogen and carbon in various proportions, and in many cases, with the addition of oxygen. Hydrogen is also one of the bases of all animal and vegetable acids; and with nitrogen it constitutes ammonia.

An oil may be formed artificially by the following process: Place a glass tube on the shelf of a pneumatic trough, send up into it three parts of fresh prepared carburetted hydrogen gas, and add to it gradually four parts of fresh prepared oxygenized muriatic acid gas. After each addition of the gas, shake the mixture; an absorption will take place, caloric will be liberated, and the tube will become filled with white vapours. When the gases have totally disappeared, an oil of an agreeable odour will be deposited, which will become yellow by exposure to the air. This is a process of the Dutch chemists for preparing olefiant gas.

* Sulphur is so plentifully diffused, that probably it was known very early: according to Pliny, it was used in his time in medicine, and for bleaching wool.

Sulphur is procured in large quantities from martial pyrites and is found in many mineral waters[†], combined with hydrogen.

What is the nature of sulphur?

Sulphur, or brimstone as it is sometimes called, is a solid, opaque, combustible[‡] substance, of a pale yellow colour, insoluble in water, very brittle, and with little taste or smell. Its specific gravity is 1.990, or nearly twice as heavy as

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and other metallic ores. It is also found in abundance in the state of native sulphur, as it is called, near several volcanos, in different parts of the world. According to Dr. Anderson there are mines of it in the kingdom of Thibet. *The Bee, vol. xvii.* 25. In the Isle of Anglesea it is sublimed from the copper ore, and collected in large chambers which are connected with the kilns by means of long horizontal flues. See Henkel's Pyritologia.

[†] Sulphur has been discovered in cresses, horseradish, and several other vegetables. It is also evolved from animal substances, during their putrefaction, in combination with hydrogen. The change which silver undergoes when immersed in an egg, shows the presence of sulphuretted hydrogen.

[‡] Sulphur during its combustion combines with oxygen, and becomes an incombustible substance. Like phosphorus, it is eminently combustible, owing to its great affinity for oxygen. See page 213.

If sulphur be kept melted in an open vessel, it at length becomes thick, as has often been observed, but I believe it has not been noticed by any writer on chemistry—that it has the peculiar property of becoming *thinner* as it cools, till it is nearly as thin as water. This is an exception to the general law, by which caloric causes the particles of bodies to recede from each other.

water. It has various uses in medicine and the arts*.

What compounds are formed by means of sulphur?

Sulphur combines with oxygen, hydrogen, nitrogen, the alkalies, the metals, some of the earths, phosphorus, &c.

What are the compounds of sulphur and oxygen?

If sulphur be kept in fusion in atmospheric air it absorbs a small quantity of oxygen, and forms oxide of sulphur†; if it be heated sufficiently to take fire, it burns with a pale blue flame, and becomes converted to *sulphurous* acid; but if sulphur be burned in pure oxygen, it absorbs the full dose of this gas, and *sulphuric* acid is the product‡.

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* Sulphur is used in large quantities for making gunpowder. When exhibited as a medicine, it penetrates to the extremities of the most minute vessels, and impregnates all the secretions; as may be perceived by those who have taken it for any length of time. Sulphur has many uses in the arts, and has been employed with advantage in stopping the progress of fermentation in wines and other fermented liquors.

† See the chapter on Oxides; also Fourcroy's System of Chemical Knowledge, vol. i. 276.

‡ For an account of the changes which take place in sulphur when it becomes oxygenized, see page 213.

What are the compounds of sulphur and the alkalies?

Sulphur will combine with potass, with soda, and with ammonia; which compounds possess several curious and interesting properties.

What are the general characteristics of the alkaline and earthy sulphurets?

They are hard substances of a brown colour, resembling the liver of animals; they absorb water from the atmosphere, and emit a fetid odour, similar to that of putrid eggs. They have the property of decomposing water, and by that process become partially converted to alkaline or earthy sulphates *.

What knowledge have we acquired of the combinations of sulphur with the earths and metals † *?*

Sulphur may be combined artificially with

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[*] The sulphurets can only exist in a state of desiccation, or at least can contain but a very small portion of water without the water being decomposed, which occasions the sulphurets to be changed into hydroguretted sulphurets.

[†] There have been instances, where people have taken frequent doses of mercurial medicine, of the human skin becoming suddenly quite black a few hours after the outward application of sulphur-ointment; to the great terror and amazement of the patient. This was occasioned by the mercury exuding through the pores of the skin to unite with the sulphur, in consequence of its affinity to that substance; and a true Æthiops-mineral was formed over the whole body.

most of the metals *, and with some earths: but many of the metallic sulphurets are found native in great abundance.

What is the origin of PHOSPHORUS?

Phosphorus is a peculiar substance, chiefly of animal † origin. It was formerly obtained from urine by a long and tedious process; but is now procured by the decomposition of the phosphoric acid which is found in bones ‡.

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* Some of the metallic sulphurets have much colour, and are employed as pigments.

Sulphuret of lime is recommended by Mr. Higgins as a cheap substitute for potass in bleaching. For the method of preparing it, consult his work on the Theory and Practice of Bleaching, published in Ireland in 1799.

† The real origin of phosphorus is very obscure: some have supposed it to be a product of the process of animalization, and several curious facts might be adduced to strengthen this opinion.

‡ Phosphorus was accidentally discovered at Hamburg in 1669, by an alchemist of the name of Brandt; and two years afterwards one Kraft brought a small piece of this substance to London, on purpose to show it to the king and queen of England. Mr. Boyle afterwards discovered the process, which he described in the Phil. Trans. for 1680. Mr. Boyle instructed Mr. Godfrey Hankwitz of London how to procure it from urine, so that he was the first who made it for sale in England; and he continued to supply all Europe with it for many years.

The writer of this has in his possession a scarce portrait, by Vertue, of this chemist in the midst of his laboratory, surrounded by his chemical apparatus; the form of which shows

What is the nature§ *of phosphorus?*

Phosphorus is a solid inflammable ‖ substance, which burns at a lower temperature, when in contact with atmospheric air, than any other simple combustible; and when saturated with oxygen, forms a peculiar acid ¶. Its specific gravity is rather more than twice that of water.

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that even at that time they had the means of accurate analysis, if they had had a rational theory to direct them. From a Latin inscription it appears that he had this print engraved to present to his customers on his taking leave of them, when about to enter upon his travels abroad to sell phosphorus.

The discovery of phosphorus proves that valuable discoveries may be made even by men who have no means of appreciating their nature. Stahl maintained that it was the *marine salt* contained in urine which yielded phosphorus.

§ Phosphorus when taken internally is poisonous. It is related in the Annales de Chimie that a great number of domestic fowls and turkeys were poisoned, merely by drinking the water in which some newly made phosphorus had been washed. Though poisonous, it has been given in *small* quantities by some French physicians, in malignant fevers, to stop the progress of gangrene, in which it succeeded beyond all hope. Nicholson's Journal, vol. iii. 85.

‖ If a piece of phosphorus be placed on the surface of water a little below the heat of boiling, it will immediately inflame. This is one characteristic of phosphorus, and distinguishes it from all other substances.

¶ Phosphorus is used in forming phosphoric acid in various chemical experiments, and in making phosphoric match-bottles. These bottles may be prepared by mixing one part of flour of sulphur with eight of phosphorus. This requires caution, and should afterward be handled with great care, lest any part of

What compounds are formed by means of phosphorus?

Phosphorus may be combined with oxygen, hydrogen, nitrogen, sulphur, or with most of the metals *, and also with some earths †.

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the mixture get under the finger nails, a small portion of which might occasion great inconvenience. When used to procure light, a very minute quantity is taken out of the bottle on the point of a match, and rubbed upon cork or wood, which produces an immediate flame.

Phosphorus is employed in making phosphoric ether, phosphoric oil, phosphoric tapers, phosphuret of lime, and various phosphoric fire-works. The methods of forming these combinations may be seen in Dr. Thomson's or in Mr. Murray's System of Chemistry.

Phosphorus, surrounded by cotton rubbed in powdered rosin, and placed under the receiver of an airpump, takes fire after exhaustion, and displays very beautiful phænomena on the gradual admission of the air. Van Marum.—Parkinson.

According to Fourcroy, phosphorus undergoes no change in oxygen gas unless heat be applied, and then it burns with great splendour. It is not even luminous in oxygen gas, or in nitrogen gas, though it be so much so in atmospheric air. Gren's Chemistry.

* Phosphorus will combine with all the metals except gold and zinc. Berthollet. It unites with iron, and forms that kind of iron called *cold-short*. Iron of such property acquired this name on account of its being very brittle when cold, though malleable when heated. Such iron may be made good and fit for most purposes by heating it with carbonate of lime. Ann. de Chim. tom. xlii. 332.

† Some animals have very peculiar phosphorescent qualities. The light of the glow-worm is well known, but the *pyrosoma*

What is the nature of these compounds?

With oxygen, phosphorus forms an oxide of phosphorus, also the phosphorous and the phos-

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atlanticum has not been described by naturalists. M. Peron, on his voyage from Europe to the Isle of France, observed this animal between 3 and 4 degrees north latitude. Its phosphorescent quality, so truly prodigious, renders it one of the most beautiful of all known zoophites, and its organization ranks it amongst the most singular. The darkness was intense when it was first discovered, the wind blew with violence, and the progress of the vessel was rapid. All at once there appeared, at some distance, as it were a vast sheet of phosphorus floating on the waves; and it occupied a great space before the vessel. The vessel having passed through this inflamed part of the sea, the crew discovered that this prodigious light was occasioned entirely by an immense number of small animals, which swam at different depths, and appeared to assume various forms. Those which were deepest looked like great red-hot cannon balls; whilst those on the surface resembled cylinders of red-hot iron. Some of them were soon caught, and were found to vary in size from three to seven inches. All the exterior surface of the animal was bristled with thick oblong tubercles, shining like so many diamonds; and these seemed to be the principal seat of its wonderful phosphorescence. In the inside also there appeared a multitude of little oblong narrow glands, which possessed the phosphoric virtue in a high degree. The colour of these animals, when in repose, is an opal yellow mixed with green; but on the slightest movement of those spontaneous contractions which it exercises, or those which the observer can at pleasure cause by the least irritation, the animal inflames, and becomes instantly like red-hot iron, and of a most brilliant brightness. As it loses its phosphorescence it passes through a number of tints successively, which are extremely agreeable, light, and varied, such as red, aurora, phoric acids*; with hydrogen, phosphuretted hydrogen gas†; with nitrogen, phosphuretted nitrogen gas; with sulphur, phosphuret of sulphur, and sulphuret of phosphorus; with the metals, metallic phosphurets‡; and with some of the earths, earthy phosphurets.

What is the origin of CARBON?

Carbon in a state of purity is known only in the diamond; but it may be procured in combination with oxygen by burning a piece of wood covered with sand in a crucible.

What compounds are formed by means of carbon?

Carbon combines with oxygen, hydrogen, nitrogen, sulphur, or phosphorus, or with iron.

What is the nature of these compounds?

Carbon with various doses of oxygen forms charcoal§, carbonic oxide||, or carbonic acid¶;

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orange, green, and azure blue: this last shade is particularly lively and pure. A further account of this curious creature may be seen in the Journal de Physique.

[*] See an account of the nature of these acids in the chapter on Acids.

[†] See page 310. [‡] See page 318.

[§] According to Dr. Bancroft, charcoal is a vegetable oxide, and, like manganese, derives its black colour from the union with oxygen. He also considers the indestructibility of charcoal to be owing to its absorption of oxygen; in which state it will resist the combined action of sun, air, moisture, &c. for hundreds of years. See Philosophy of Permanent Colours, page 48.

[||] See the chapter on Oxides for an account of these combinations. [¶] See page 227.

with hydrogen and caloric, carburetted hydrogen gas[*]; with nitrogen and caloric, carburetted nitrogen gas; with sulphur, carburetted sulphur; with phosphorus, phosphuretted carbon; and with iron, plumbago, or carburet of iron[†].

Some of these compounds having been already examined, it will now be expedient to consider the other combinations of carbon;—therefore, what is charcoal?

Charcoal is the coaly residuum of any vegetable burnt in close vessels[‡].

What are the characters and appearances of charcoal?

Charcoal is generally black, sonorous and brittle, very light, and destitute of taste or smell[§].

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[*] See page 311.

[†] See page 337.

[‡] Charcoal for common purposes is made by a less expensive process. The wood is disposed in heaps regularly arranged, and covered with earth, so as to prevent the access of any more air than is absolutely necessary to support the fire, which is kept up till all the water and oil are driven off; after which the fire is extinguished by shutting up all the air-holes. A more œconomical method is first to collect the acetic acid from the wood, by dry distillation in large iron cylinders; and then the residuum in the cylinders will be charcoal of the best quality. By this process, his majesty's gunpowder works have for some time past been supplied with charcoal.

[§] Charcoal is so porous that it may be seen through with a microscope; and however large the piece, it may be readily blown through.

What are the properties of charcoal?

Charcoal is a powerful antiseptic*; has great affinity for oxygen†; is unalterable and indestructible by age‡; and, if air and moisture be excluded, is not affected by the most intense heat.

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* "All sorts of glass vessels and other utensils may be purified from long retained smells of every kind, in the easiest and most perfect manner, by rinsing them out well with charcoal powder, after the grosser impurities have been scoured off with sand and potash. Rubbing the teeth and washing out the mouth with fine charcoal powder will render the teeth beautifully white, and the breath perfectly sweet, where an offensive breath has been owing to a scorbutic disposition of the gums. Putrid water is immediately deprived of its offensive smell by charcoal." Crell's Journal, vol. ii. 170.

Meat, which is only a little tainted with putridity, may at once be made sweet by charcoal: and if common raw spirits be agitated with charcoal, they will be deprived of their bad flavour. A gentleman in the spirit trade however informs me, that spirits treated in this way are very apt to resume the old flavour, if kept in the cask only a few months.

† Charcoal, from its affinity with oxygen, will decompose the sulphuric and nitrid acids. It decomposes the latter with great rapidity. If the charcoal be dry and finely powdered, and the acid strong, and allowed to run down the inner side of the vessel to mix with the charcoal, it will burn rapidly, giving out a beautiful flame, and throwing up the powder so as to resemble a brilliant fire-work.

‡ "The beams of the theatre at Herculaneum were converted into charcoal by the lava which overflowed that city; and during the lapse of seventeen hundred years, the charcoal has remained as entire as if it had been formed but yesterday, and it will probably continue so to the end of the world. The in-

To what uses is charcoal applied?

Charcoal is used in large quantities in making gunpowder; it is employed as an antiseptic in purifying rancid oils, &c.; in decomposing the sulphuric acid; and for many other purposes, by the chemist and the manufacturer §.

Is charcoal a simple or a compound substance?

Charcoal is a compound substance; it is an

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corruptibility of charcoal was known in the most ancient times; the famous temple at Ephesus was built upon wooden piles, which had been charred on the outside to preserve them." Watson's Essays, vol. iii. 48.

" It is said that there still exists charcoal made of corn in the days of Cæsar, which is in so complete a state, that the wheat may be distinguished from the rye." Willich.

" About forty years ago a quantity of oak stakes were found in the bed of the Thames, in the very spot where Tacitus says that the Britons fixed a vast number of such stakes, to prevent the passage of Julius Cæsar and his army. They were *charred* to a considerable depth, retained their form completely, and were firm at the heart." Dr. Robison. The ancients wrote with levigated charcoal, the most indestructible substance we know; and accordingly, the writings found in Herculaneum are still a perfect black. Ib. vol. ii. 480.

Casks charred in the inside are now used to preserve water in sea voyages; and such casks are found to preserve the water uncorrupted. Dr. Black, vol. ii. 285.

§ Charcoal is used by mathematical instrument-makers and engravers to polish their brass and copper plates. Plates of horn and lanthorn leaves are polished with it. It is also much used by artists in tracing the outlines of drawings. See Additional Notes, No. 2.

oxide of carbon, or the woody fibre partially oxidized; it also contains hydrogen *, and a portion of fixed alkaline salt and earth; but these are rather adventitious than essential ingredients.

What is carbon?

Carbon is the base of charcoal, divested of all impurities.

What is the most striking property of pure carbon?

Carbon is capable of crystallization, though not by art, and in that state it is called *diamond* †.

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* Charcoal always contains hydrogen, which it retains after the most powerful calcination. It is the want of hydrogen which renders the diamond much less combustible than charcoal. To the absence of oxygen, this may in part be attributed, as plumbago and anthracolite, ~~being~~ both oxides of the first degree, are less combustible than charcoal. For the same reason, manufacturers obtain higher degrees of heat with *coke* than with charcoal; for coke, being less oxidized than charcoal, requires a higher temperature for its combustion. To those manufacturers who reside near coal-works where the small coal is fit for making coke, I take this opportunity of recommending to their attention the coke ovens of the duke of Norfolk. See Additional Notes, No. 50. The small of some coal will not coke.

† The diamond is pure carbon, entirely divested of oxygen; charcoal contains 64 parts diamond and 36 oxygen in every 100; carbonic acid has 28 parts charcoal and 72 of oxygen, or 18 diamond and 82 oxygen. The diamond is chiefly found in the kingdom of Golconda in Asia, and in Brazil. It always occurs crystallized: indeed, if not, it would be carbon and not diamond. See a note respecting the diamond under the article

What other properties has carbon?

Carbon has the property of de-oxidizing the oxides of metals and other combustible sub-

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Steel, in the chapter on Metals; where you have an additional proof that diamond is simple carbon. It is wonderful that Newton, who had no chemical means of examining the diamond, should have conceived the idea of its inflammable nature. See Additional Notes, No. 35.

Mr. Tennant has satisfactorily shown, that the diamond is pure carbon, carbon crystallized. See Phil. Trans. for 1797. The diamond is the hardest substance in nature, and one of its rarest productions. From its hardness it is employed for sawing and boring the hardest stones. "Diamonds are usually found in an ochreous yellow earth, under rocks of grit stone; they are likewise found detached in torrents, which have carried them from their beds. They are seldom found above a certain size. The sovereigns of India reserve the largest, in order that the price of this article may not fall. Diamonds have no brilliancy when dug out of the earth, but are covered with an earthy crust." Fourcroy. Diamonds are also found in considerable numbers in the island of Borneo. Whenever the mines are searched for them, an overseer attends, and watches the workmen with great care, that the largest may be secured for the sovereign prince. Notwithstanding, they are frequently conveyed away clandestinely by the workmen, who will swallow them. Von Wurmb's History of Borneo.

A minute account of the diamond mines of Brazil may be seen in Ann. de Chim. tom. xv. 82; and in Nicholson's Journal, 4to, vol. i. 24.

The usual method of calculating the value of diamonds, is by squaring the number of carats, and then multiplying the amount by the price of a single carat: thus, supposing one carat to be worth 2*l.*, a diamond of 8 carats is worth 128*l.*, being 8 × 8 × 2.

stances*, and of uniting with their oxygen to form carbonic acid †.

Does carbon enter into any other combinations?

Carbon is found in large proportions in bitumen and pit-coal ‡; it seems to be ready formed

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A carat is 4 grains. *Polished* diamonds, without blemish, are worth about 6*l.* per carat.

In the year 1772, the empress of Russia purchased a diamond that weighed 779 carats. She paid the immense sum of twelve tons of gold for it, and granted a pension of 4000 roubles to the vendor.

* Charcoal has such a powerful affinity with oxygen, that in a proper degree of heat it will abstract it from all other substances.

† The merit of the discovery of carbonic acid is due to the illustrious Dr. Black of Edinburgh. Those who have not been in the habit of reading the early chemical writers, can have no idea of the service which this great man has rendered the science by his very accurate investigation of this compound.

‡ There are good reasons for supposing that bitumens and pit-coal have been formed in the bed of the sea by the decomposition and deposition of animal matters. The quantity of volatile alkali which these substances yield on distillation favours this opinion. An interesting paper by Mr. Kirwan, on the proportions of carbon in the different kinds of coal, will be found in Nicholson's Journal, 4to, vol. i. 487.

See an ingenious paper by Mr. Hatchett, on the origin of bitumen, &c., in the Phil. Trans. for 1804. See Additional Notes, No. 39.

An interesting account of the springs of fossil tar near Shrewsbury, and at Colebrook Dale, may be seen in Archdeacon Plymley's View of the Agriculture of Shropshire.

also in vegetables; and enters into most animal and some mineral substances §.

What is the proportion of carbon in pit-coal?

Pit-coals vary in quality, according to the different proportions of carbon and bitumen which they contain ‖; but carbon is the *chief* ingredient

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§ Charcoal has the property of forming an intimate union with the fixed alkalies, if fused with them.

Plumbago contains a small quantity of oxygen: it is therefore diamond in its first state of oxidizement, or an oxide of the first degree; charcoal, an oxide of the second; carbonic oxide, of the third; and carbonic acid, the product of the complete oxidizement of carbon.

‖ The immense quantity of pit-coal which is deposited beneath the surface of the earth is truly astonishing, and affords abundant matter for reflection. This kind of fuel is consuming day after day in incalculable quantities; and so great is the store, that there is no probability of its being exhausted for ages yet to come. Supposing the formation of pit-coal to be owing to the deposition of marine animal matter; the same process must be still going on, and the inmost recesses of the present seas may be receiving the materials of fuel for the inhabitants of new continents in the most remote periods of the world. The wise œconomy of the great Author of Nature, in this constant circulation of the elements of matter, is equalled by nothing but his own infinite beneficence.

"Who, not content
By one exertion of creative power
His goodness to reveal; through ev'ry age,
Through every moment up the tract of time
Adjusts, accommodates, and blesses all."

On the formation of coal, consult "Mr. Williams's History of the Mineral Kingdom," and "Parkinson's Organic Remains."

in all. What are called *slaty* coals contain also from 10 to 40 per cent. of earth *; and some coals contain a considerable quantity of *martial pyrites*, the sulphuret of iron.

What is the use of carbon in the vegetable kingdom?

Carbon is not only a component part, but forms nearly the whole of the solid basis of all

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* There are four species of coal, very distinct from each other. The *graphite* of Werner, or plumbago; the *anthracolite*; the *jet*, or cannel coal; and the common coal.

One hundred parts of plumbago contain 90 charcoal and 10 iron. The best quality, which is found at Keswick in Cumberland, is used in making pencils.

Anthracolite, or coal blend, is distinguished from other coal by burning without flame. It is composed of 64 charcoal, 33 silex, and 3 parts of other earths.

Jet is composed of bitumen and charcoal: 75 parts charcoal, 22 parts bitumen, and 2 parts earth.

Common coal is composed of bitumen and charcoal in different proportions, according to its quality and the places whence it is procured At Newcastle upon Tyne, martial pyrites are often found mixed with the coal, in such abundance as would render the coal unsaleable; but persons are employed to pick out these pyrites and remove them to a proper situation, where in process of time they become acidified, and fit for the production of green vitriol. See an account of this process under the article Salts of iron. This species of coal, when in contact with water, is apt to be decomposed, and to burn spontaneously. Ships at sea have sometimes been suspected to have been lost by this means. His majesty's ship Ajax of 74 guns lately took fire in the middle of the night on a station in the Mediterranean, and no cause for that dreadful catastrophe has yet been assigned.

vegetables, from the flower of the garden to the oak of the forest †.

If carbon forms so large a part of all vegetables, what occasions that infinite variety which we observe in the vegetable creation?

We are in a great measure strangers to the œconomy of vegetables; but much of this variety may be attributed to the different modifications of carbon ‡, as well as of the other principles which enter into their constitution §.

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† It has been discovered that air which has been spoiled by the breathing of animals is peculiarly fitted for the vegetation of plants: no doubt this is owing to its containing a larger portion of carbonic acid.

By the analysis of soils it has been proved, that of all the substances found in the mixture of earths which constitute a soil, calcareous earth contributes most certainly to its fertilization. This probably proceeds from the carbonic acid. An interesting account of some experiments on manures, by Mr. Arthur Young, on a small scale, may be seen in the Retrospect, vol. i. 118.

‡ Vegetables have the power to absorb oxygen from the atmosphere, and to transmit it to the absorbent vessels of the roots. It cannot be questioned but that this oxygen becomes useful in vegetation, by converting the carbon of manures into carbonic acid. See Additional Notes, No. 48.

The operation of paring and burning turf, which is always found by farmers extremely serviceable to their lands, is doubtless rendered universally advantageous from the carbonaceous matter which is produced by the burning.

§ When we consider the small number of simple substances which enter into the composition of plants, how astonishing is

What products of vegetation are there which are indebted to carbon for their formation?

Carbon not only constitutes the base of the woody fibre, but is a component part of sugar, and of all kinds of wax, oils, gums, and resins, of which there are many varieties.

How are these substances formed by the vegetating organs of plants?

All living vegetables have the power of decom-

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the variety that has been afforded us by the bounty of nature! The species of vegetables already known are more than 40,000, and large additions are daily making to this number by new discoveries. Is it possible that so bountiful a provision can have been made by nature ultimately for the use of man?—Yes: "for him she has covered the earth with plants; and though their species be infinite in number, there is not one but may be converted to his use. She has selected some out of every class to minister to his pleasures, or his support, wherever he shall please to fix his habitation. Others serve for his bed, for his roof, for his clothing, for the cure of his diseases, and for the fire of his hearth." St. Pierre.

Fourcroy has remarked "that vegetables may be considered as beings intended by nature to *begin* the organization of crude matter, and to dispose the primitive materials of the earth and atmosphere in order to become the source of life, and consequently to establish a communication between minerals and animals; from whence it follows, that plants are truly chemical apparatus employed by nature to produce combinations which would not take place without them." Nature is as admirable in the simplicity of her means, as in the constancy and regularity of her operations.

posing water*, and of combining in different proportions the hydrogen of the water with the carbon of the soil, as well as with that of the carbonic† acid of the atmosphere‡, to form the numberless productions of vegetable nature.

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* When we decompose water, we can do it only by abstracting its oxygen by combustible substances, and liberating the hydrogen. Vegetables effect this in a different way; they preserve the hydrogen, and set the oxygen free. This process of Nature, in the latter instance, has been noticed in a former chapter. See page 84.

Berthollet has remarked, that the decomposition of water must always take place to give rise to substances of a resinous character, when the vegetation is performed without the concurrence of foreign bodies. Chemical Statics, vol. ii. 393.

† Van Helmont planted a willow, weighing fifty pounds, in a certain quantity of earth, covered carefully with sheet lead; he kept it in this state for five years, watering it with distilled water; and at the end of that time the tree weighed 169 pounds three ounces; the earth in which it had vegetated, being weighed at the same time, was found to have lost only three ounces. This was repeated by Mr. Boyle with a similar result. See Additional Notes, No. 57.

‡ Senebier found, that plants watered by water impregnated with fixed air, grew more luxuriantly than plants watered as usual, and that when insulated from every substance which could afford it to them immediately, they acquired carbon by the decomposition of carbonic acid gas in the atmosphere. This they take in by the under surface of their leaves, as well as by their roots.

It appears from hence that *solid* matter is not necessary to the growth of vegetables; and that they owe their increase chiefly to the decomposition of water and carbonic acid. See page 84.

If carbon and hydrogen enter into the composition of all these substances; how is it that one vegetable affords gum, another resin, another oil, &c. * ?

The infinite variety which there must be in the internal organization of vegetables, to enable different orders to prepare such different substances from the same elements, renders this subject too intricate and minute for our investigation. We feel the insufficiency of our faculties—" The will of God is the ultimatum of all human knowledge."

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* Carbon and hydrogen are not the only principles which enter into the composition of all these substances. Most of them contain a proportion of oxygen also, as may be seen by the following statement:

Olive oil	Carbon	79
	Hydrogen	21
		100

Sugar	Carbon	28
	Hydrogen	8
	Oxygen	64
		100

Resin	Carbon and hydrogen proportions unknown.	Saturated with oxygen.

Wax	Carbon	82	Saturated with oxygen.
	Hydrogen	18	
		100	

Gum	Carbon	23
	Hydrogen	11
	Oxygen	65
	Nitrogen & lime	1
		100

The formation of resin and wax has lately been explained thus: That when a volatile or a fixed oil is expelled out of plants, and has its surface expoſed to the air, the first becomes a resin by losing hydrogen, the second a wax by absorbing oxygen.

Is it known what other substances are employed by nature for the formation and growth of vegetables?

All orders of vegetables are produced from four or five natural substances, viz. caloric, light, water, air, and carbon*. Nature has required

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* It has been shown that water and atmospheric air are the natural food of plants. Caloric is necessary to enable vegetables to decompose water and air; and light is equally requisite to give a part of the oxygen of these substances a gaseous form, and to put it in a proper state to be thrown off by the leaves. The other portion of oxygen goes to the formation of sugar and the vegetable acids. The analysis of vegetables confirms this theory; for, however they may be examined, the result is always the production of oxygen, hydrogen, and carbon. Some plants yield also a portion of silex, and others lime; but these no doubt are taken up by the roots from the soil. See Mr. Davy's paper on silex found in the epidermis of reeds, &c. in Nicholson's Journal for May 1799.

When we consider that the many thousand tribes of vegetables are not only all formed from a few simple substances, but that they all enjoy the same sun, vegetate in the same medium, and are supplied with the same nutriment, we cannot but be struck with the rich œconomy of Nature, and are almost induced to doubt the evidence of those senses with which the God of Nature has furnished us. That it should be possible so to modify and intermingle a few simple substances, and thence produce all the variety of form, colour, odour, &c. which is observable in the different families of vegetables, is a phænomenon too astonishing for our comprehension. Nothing short of Omnipotence could have provided such a paradise for man.

" Soft roll your incense, herbs, and fruits, and flowers,
In mingled clouds to Him, whose sun exalts,
Whose breath perfumes you, and whose pencil paints."

only these in order to form even the most exquisite of her productions.

> "With hues on hues expression cannot paint,
> The breath of Nature and her endless bloom."

How is it that such an inexhaustible variety of forms, colours, tints, odours, tastes, qualities, &c. so conspicuous in this kingdom of Nature, can be produced from such a scanty number of natural substances?

The means by which all this is effected are unknown to us; but this we know, that "these wonderful harmonies are not in the nature of the elements, but in the will of Him who has ordained them, in subordination to the wants of his numerous creatures*."

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* The various orders of vegetables provided in every part of the globe, for the countless forms of animated existence, are eminently illustrative of the provident care of the Creator, and show us how great and how good is the Father of the families of the whole earth. The following passage from St. Pierre is so well calculated to impress this truth, that it is unnecessary to apologize for its introduction:—"The sluggish cow pastures in the cavity of the valley; the bounding sheep on the declivity of the hill; the scrambling goat browses among the shrubs of the rock; the duck feeds on the water plants of the river; the hen, with attentive eye, picks up every grain that is scattered and lost in the field; the pigeon, of rapid wing, collects a similar tribute from the refuse of the grove; and the frugal bee turns to account even the small dust on the flower. There is no corner of the earth where the whole vegetable crop may not be reaped. Those plants which are rejected by one are a

What is the office of carbon in the animal *kingdom?*

As carbon is a necessary part of sugar, of oils, &c., it consequently enters into the composition of animal milk, and of animal oils and fat; it is also found in albumen, gelatine, fibrina, and animal urine.

Does carbon enter into any mineral combinations?

It is imagined that most of the metals may be combined with carbon; but at present we know only its combinations with iron and zinc†.

What does carbon form when combined with iron?

In one proportion it forms cast iron‡; in another steel; and in a third proportion plum-

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delicacy to another, and even among the finny tribes contribute to their fatness. The hog devours the horse-tail and hen-bane; the goat, the thistle and the hemlock. All return in the evening to the habitation of man, with murmurs, with bleatings, with cries of joy, bringing back to him the delicious tribute of innumerable plants, transformed, by a process the most inconceivable, into honey, milk, butter, eggs, and cream."

† We have reason to believe that carbon unites with metals only by fusion; and that the different kinds of carburetted metals which are found, have all undergone intense heats at some period of the world.

‡ Cast iron acquires carbon in the smelting furnaces during its fusion.

bago, generally, though improperly, called black lead *.

What is the proportion of carbon in cast iron?

Upon an average cast iron contains, according to the analysis of Bergman, about one forty-fifth of its weight of carbon †.

What quantity of carbon enters into the composition of steel?

Steel is iron combined with about one part of carbon in two hundred of iron ‡.

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* The name which this substance has so long borne shows how necessary it was to give a new nomenclature to the science. It is now known, that what has been called black *lead* owes its metallic quality to *iron*; and that there is no lead in its composition. Many other instances might be adduced, in which the names of substances have given false ideas of their nature and properties: thus, white and green copperas contain no *copper*, but other metals.

† Cast iron does not owe its brittle qualities to the carbon which is combined with it; for that iron which contains most carbon is found to be the best metal. Cast iron generally contains a portion of phosphuret of iron, and always a quantity of oxygen: these substances give it its hard brittle quality. To convert cast iron into wrought iron the metal is submitted to a long intense heat, by which means the carbon burns, and uniting with the oxygen, both go off in the state of carbonic acid gas. The iron is then carried to the forge hammer, which beats out the phosphuret of iron, and brings the particles closer together. When the iron is required to be pure and good, it undergoes repeated hammering till it is brought to the desired quality.

‡ To procure steel, nothing more is necessary than to heat

How is carbon combined with iron to form plumbago?

Carburet of iron, or plumbago §, has been found to consist of nearly nine parts carbon to one of iron.

What is the nature of the combination of carbon with zinc?

Carbon combines largely with zinc; but the nature of this combination is not much known.

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good pure iron for several hours in a proper furnace, with charcoal, or any substances proper for furnishing a sufficient quantity of carbon, which is absorbed by the iron in the process. Iron has so great an affinity for carbon, that it is even capable of decomposing carbonic acid in a high temperature. See Philosophical Magazine, vol. ii. where there is an account of a late mode of making steel by fusing soft iron in crucibles, with carbonate of lime.

§ Plumbago is found in great plenty at a place called Burrow-dale, in Cumberland. Its chief use is in making pencils, called black lead pencils. It is likewise useful to rub over wooden machinery to prevent friction.

According to Fabroni, plumbago is formed in the humid way, at the bottom of certain wells in the kingdom of Naples, from whence it is regularly collected every six months.

Carburet of iron is found also on various parts of the continent. It often occurs in mountains, in the midst of beds of quartz, or calcareous earth. It has lately been found crystallized in octahedrons.

Plumbago (like charcoal) is indestructible by heat, unless with the presence of atmospheric air. It is therefore much used for making crucibles and portable furnaces. It protects iron from rust, and on that account is rubbed on various ornamental cast iron works, such as the fronts of grates, &c.

You said that carbon formed an acid by its union with oxygen: how is that effected[*] *?*

Carbon has so great an affinity to oxygen, that when assisted by heat it will take it from most substances with which it may be combined; in certain proportions they then form carbonic acid gas[†].

What quantity of oxygen is necessary to convert carbon into carbonic acid?

Twenty-eight parts by weight of carbon require 72 parts of oxygen to saturate them; so that

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[*] The pupil may be satisfied of the composition of carbonic acid by the following experiment: Take one of those glass receivers generally used for deflagrating the gases; fill it with oxygen gas, and invert it in a shallow pan of water. Then having a piece of ignited cortical part of charcoal ready, suspend it by a wire to the stopper of the receiver, and immerse it quickly in the gas. The charcoal will be seen to burn for a considerable time with the greatest splendour, throwing out the most beautiful corruscations. When the inflammation is over the oxygen gas will be consumed, and the water will be found to be impregnated with carbonic acid; and if some transparent lime-water be poured in, the whole will become opaque from the carbonate of lime now formed.

[†] There can be no doubt that carbonic acid is formed by the union of carbon with oxygen; for steel may be made as effectually by the decomposition of carbonic acid, as it can by the direct union of iron with carbonaceous matter.

Carbon takes a gaseous form also by combining with hydrogen and caloric, and forms what is called carburetted hydrogen gas. Likewise the gas discovered by Dr. Priestley, and which Mr. Cruickshank named the *gaseous oxide of carbon.*

100 parts of carbonic acid are composed of twenty-eight parts of carbon, and seventy-two of oxygen ‡.

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‡ Oxygen has a greater affinity for carbon than for any other substance. Mr. Lavoisier burned small quantities of charcoal in pure oxygen gas in close vessels, and found that a part of this gas was converted into fixed air. He separated this from the rest of the oxygen by means of caustic alkali, and weighed the alkali after it had attracted the fixed air. He also expelled the air again by an acid, and examined its bulk. Thus he learned the weight of the air, and what measure of it had been produced. Then, comparing this weight with that lost by the charcoal which had been consumed, he found it to exceed greatly the weight of the charcoal, and was exactly equal to the weight of the charcoal added to that portion of the oxygen gas which had been changed into fixed air. Dr. Black, vol. ii. p. 100.

The composition of carbonic acid has been further proved by analysis, as it has actually been decomposed, and the charcoal exhibited entire. See Mr. Tennant's Experiments on fixed Air, in Phil. Trans. vol. lxxxi. 181. When a diamond is burnt, the proportions are different to the above, for it is the purest carbon we are acquainted with. It requires to form 100 parts of carbonic acid, only 17.88 of diamond, and 82.12 of oxygen. In burning diamond, carbonic acid is the product, and there is *no* residue. One part of charcoal absorbs 2.527 of oxygen, and produces 3.575 of carbonic acid; whereas one part of diamond absorbs more than four parts of oxygen, and produces five of carbonic acid.

More attention has been paid to the appearances in the combustion of the diamond, by Sir George Mackenzie, than by most others who have investigated this subject. See Nicholson's Journal, 4to, vol. iv. 103.

Carbonic acid gas may be readily procured for experiment by

What is the specific gravity of carbonic acid?

Carbonic acid can only be exhibited in the form of gas; each cubical inch weighs near three quarters of a grain.

What are the properties of carbonic acid gas?

Carbonic acid gas is invisible and elastic, is twice as heavy as atmospheric air*, will mix with vital air, may be combined with water, to which it gives a brisk and acidulous taste †, and will occasion the death of animals that are obliged to breathe it ‡.

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pouring a little diluted sulphuric acid into a phial, or a retort, upon a little pulverized chalk. An action will immediately commence; and if one end of a bent tube be made fast in the neck of the phial, and the other brought under the mouth of a jar filled with water, and inverted in a vessel of water, the gas will pass from the mixture into the inverted jar.

[*] This gas, on account of its density, may be poured from one vessel to another like water, or may be drawn from a cask by a cock like other fluids. In consequence of its great specific gravity it is frequently found at the bottom of mines, wells, &c. See pages 342, 343.

[†] In order to saturate water with this gas, it is necessary to subject it to a considerable degree of pressure. The persons who are engaged in making the acidulous soda water have peculiar conveniences for this purpose. Cyder, perry, bottled beer, and other fermented liquors, owe their briskness and sparkling to the presence of this gas.

[‡] Carbonic acid has also the property of rendering lime soluble in water. As the carbonic acid escapes by exposure to the air, the calcareous matter is precipitated from the water which

In what states does carbonic acid exist in Nature?

Carbonic acid is found in Nature in three different states, viz. in gas, in mixture, and in chemical combination; it is perhaps the most abundant of all the native acids§.

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held it in solution; whence arise the various earthy incrustations found in different parts of the world. Fourcroy has very aptly remarked, that "when natural history was less enlightened by chemistry, springs of this kind were called *petrifying* waters, and were by the vulgar reckoned among the number of miracles."

Some very interesting remarks on the utility of this property of certain waters to dissolve calcareous earth may be seen in Parkinson's Organic Remains, vol. i. page 379.

At Guancavelica in Peru, artists obtain statues and even stones for building, by filling moulds frequently with a mineral water of that district.

§ Plants of all kinds give out carbonic acid gas while growing in the shade; but when assisted by the rays of the sun, there is reason to think that the plants have the power of decomposing this acid; for then the leaves give out only oxygen gas. Annales de Chimie, tom. xiii. p. 318.

Mons. Saussure has shown, that when vegetables decompose carbonic acid gas, they throw off only half of the oxygen; and that the other half, with the whole of the carbon, enters into the composition of the plant. He also says, that the leaves absorb oxygen gas, in darkness, and emit an equal quantity when exposed to the light. If this account of vegetation be correct, growing vegetables deteriorate the atmosphere in the night and purify it in the day. The roots, wood, and petals perform no inspiration. Phil. Mag. vol. xx. 307.

What instances are there of its natural existence in the state of gas?

It is found in the proportion of one per cent.* in atmospheric air; also in caverns and mines, where it is called the choke damp†.

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* The use of this gas in atmospheric air is not accurately known. Perhaps the large quantity of carbonic acid, which is perpetually forming by the processes of respiration and combustion, seizes the putrid exhalations which arise from the earth, and preserves the atmosphere from being contaminated with them. We know that *carbon* has the property of uniting chemically with putrid miasmata, and rendering them innoxious. It seems likely then that one per cent. of carbonic acid gas is diffused throughout the atmosphere, in order that it may be ready to arrest every malignant vapour at the moment of its formation by the putrefactive process. Without some such contrivance we should be in perpetual danger of pestilential contagion.

† The floor of the Grotto del Cane, in Italy, is lower than the door, and this hollow is always filled with fixed air, which can rise no higher than the threshold, but there flows out like water. It has been a common practice to drive dogs into this cavern, where they suffer a temporary death, for the entertainment of the passengers: but a man enters with safety, because his mouth is far above the surface of this deleterious air. From the loss of so many dogs in this cavern it acquired the name of the Grotto del Cane. The lake of Averno, which Virgil supposed to be the entrance to the infernal regions, evolves so large a quantity of this gas, that birds flying over it drop with suffocation. Fatal accidents have happened to persons who have incautiously descended into brewers' vats before they have been purified from this gas.

Carbonic acid gas so often occupies the bottoms of wells, *What instances are there of carbonic acid being found mixed with fluids?*

It is abundant in Spa-water, and in some other acidulous waters‡.

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that workmen ought never to venture into such places without previously letting down a lighted candle. If the candle burns, they may enter with safety; if not, a quantity of *quick lime* should be let down in buckets, and gradually sprinkled with water. As the lime slacks it will absorb the carbonic acid gas, and the workmen may afterwards descend in safety.

Fatal accidents often happen from burning charcoal in chambers; as whenever charcoal is burned this gas is formed. Workmen have also lost their lives by sleeping too near limekilns, where this gas is extricated in abundance. Whenever persons are discovered in such situations, or are suffering from the effects of carbonic acid gas, the same means should be made use of as are directed by the Humane Society, in cases of apparent death from drowning: or, when it can be done without loss of time, atmospheric air, or even pure oxygen gas, should be forced into the lungs.

Mr. Henry has suggested to naturalists, that butterflies, and other insects, the colours of which it is desirable to preserve for the purpose of cabinet specimens, may be suffocated in carbonic acid gas, better than by the common mode of killing them with the fumes of sulphur.

Carbonic acid gas has been given medicinally with success, and has proved a powerful antiseptic. Meat which has been sealed up in it has been known to have preserved its texture and appearance for more than twenty years.

‡ These waters have a pleasant light acidity and briskness, and sparkle in the glass like fermented liquors; which is well known to be the case with water when artificially impregnated with fixed air. Dr. Percival esteems it highly medicinal in pulmonic consumptions, and in malignant fevers.

By great pressure water may be combined with more than

In what substances is carbonic acid found chemically combined?

Carbonic acid is found in all parts of the world in great plenty, in combination with the alkalies, in earths, and in stones; particularly in chalk, limestone, and marble*.

What is the effect *of the combination of carbonic acid?*

Carbonic acid renders mild and salutary some of the most acrid and destructive of all known substances†.

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twice and a half of its own bulk of carbonic acid gas. Such waters are considerably stronger than those afforded by Nature, and have much greater medicinal effects.

A description of a proper apparatus for impregnating water with this gas will be found in Bouillon la Grange's Chemistry, vol. i. 93.

[*] Carbonic acid is found combined with alkalies and with several metallic oxides. These combinations are called carbonates.

A cubic inch of marble contains as much carbonic acid in combination as would fill a six-gallon vessel when in the state of gas. Dr. Black's Lectures, vol. i. 26, preface.

Marble contains of carbonic acid 407 parts in 1000.
Crystals of soda . . . . 423 parts ditto.
Mild volatile alkali . . . . 533 parts ditto.
Carbonate of magnesia . . . . 594 parts ditto.

[†] We all know the causticity of pure quick-lime, and the corrosive qualities of the fixed alkalies; but whenever these substances are *fully* saturated with carbonic acid, the first forms mild calcareous earth, (or chalk) and the others mild

How is the carbonic acid separated from alkalies and earths?

Carbonic acid may be disengaged by all the other acids; but it is usually separated from alkalies by the addition of quick-lime, which absorbs this acid, and thus is converted into carbonate of lime‡.

How is carbonic acid usually procured for chemical purposes?

Carbonic acid gas may be collected in abundance from the surface of fermenting liquors; but it is more commonly obtained by pouring sulphuric acid upon a mixture of chalk, or marble and water§.

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neutral salts, applicable to many purposes of medicine and domestic œconomy.

‡ Though the alkalies readily part with their carbonic acid to caustic, calcareous earth, yet they have a a great affinity to this acid, as may be shown by the following interesting experiment: Fill a jar with carbonic acid gas, then pour into it a small quantity of a solution of *caustic* potass, or soda; and having tied the mouth over with a wetted bladder, move the vessel so as to spread the alkali over its inner surface, when a vacuum will be quickly formed by the absorption of the gas, which will appear by the bladder being pressed inwards by the weight of the atmosphere. If this experiment be made in a glass vessel, its surface will be seen covered with crystals of the alkali, as the carbonic acid always promotes the crystallization of the fixed alkalies.

§ This process beautifully demonstrates the indestructibility of matter: in it we remark that the gas which has bound to-

How do you account for the production of carbonic acid gas in the process of fermentation?

In all vinous fermentations a decomposition of the saccharine matter takes place; and a part of the disengaged oxygen, uniting with a part of the carbon of the sugar, forms carbonic acid*. A decomposition also of part of the water of solution perhaps promotes the process.

What is the cause of vinous fermentation?

The cause of vinous fermentation is not well understood; but it appears to be a spontaneous commotion that takes place on the decomposition of vegetable substances, in certain favourable circumstances of temperature and solution; and it is a process which Nature employs for their destruction†.

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gether the massy rock for a thousand years, is still carbonic acid, and is as capable of forming a variety of combinations as any carbonic acid would be if recently produced.

How œconomical is Nature in all her proceedings! See Additional Notes, No. 25.

* It has been matter of surprise to me that no advantage has been taken of the vast quantities of carbonic acid gas, which are perpetually escaping from the vats of the large breweries in this metropolis. It might surely be collected, and applied to many useful purposes. The benefit which is derived from *yeast* in putrid diseases, is due to its carbonic acid. An interesting paper on the use of this remedy may be seen in the sixth volume of the Philosophical Magazine, 56.

† It is now pretty generally known that no substances are capable of fermentation but such as have been elaborated by the

What circumstances are necessary to produce vinous fermentation?

The presence of vegetable matters, of water, of sugar‡, a certain degree of heat§, and free egress for the carbonic acid to escape as it is generated.

Can you at all account for the change which is effected in saccharine liquors by fermentation?

By the process of fermentation the sugar,

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principle of animal or vegetable life. See a memoir on this subject by Fourcroy, part iii. chap. 22.

Fourcroy admits five distinct species of vegetable fermentations, viz. the saccharine, or that which forms sugar, the vinous, the acetous, the colouring, or that which is developed by the maceration of the indigo-plant, and the putrid. See Fourcroy's System of Chemical Knowledge, vol. viii. 148. Some writers have spoken of another kind of vegetable fermentation, viz. the panary, or that which manifests itself in making bread; but surely this is a species of the acetous, for its tendency to acidity is very evident.

‡ It appears from several late experiments carefully made, that sugar is composed entirely of hydrogen, oxygen, and carbon. Mr. Cruickshank made many experiments on fermentation, and invariably found, that whenever he added a fourth substance to the three which compose saccharine matter, no fermentation took place. He tried lime, and at another time a small quantity of potash; and the addition of either prevented fermentation. See Mr. John Thomson's Notes to Fourcroy, vol. iii. 128; also Dr. Rollo on Diabetes; and Additional Notes, No. 49.

§ To produce vinous fermentation, it is necessary that the matters subjected to that process should be placed in a temperature not lower than 55 degrees of Fahrenheit. No kind of fermentation is ever known below the freezing point.

which is a vegetable oxide*, parts with a portion of its oxygen to form carbonic acid, and becomes converted into alcohol by being thus partially deoxidized.

Does sugar then become spirit of wine, or alcohol, merely by losing a part of its oxygen?

No: it parts with a portion of its carbon at the same time, in the form of carbonic acid gas, and a new arrangement of the remaining principles, both of the sugar, and of the water in which it is dissolved, takes place, furnishing an increased proportion of hydrogen, in order to form vinous liquor †.

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* Lavoisier having analysed sugar, found that it was composed of hydrogen, oxygen, and carbon, in the following proportions: Hydrogen 8 lbs., oxygen 64 lbs., carbon 28 lbs., in every 100 pounds weight of sugar. Lavoisier's Elements, 188. Having subjected 100 lbs. of sugar to fermentation, he found the products (viz. alcohol, carbonic acid, and acetous acid,) when analysed, contained the precise quantities of hydrogen, oxygen, and carbon, which were contained in the original sugar. The particular detail which he has given of these experiments is extremely interesting. Ibid. p. 185 to 197. In consequence of the results which were obtained, he remarks, "The effect of the vinous fermentation upon sugar is thus reduced to the mere separation of its elements into two portions: one part is oxygenized at the expense of the other, so as to form carbonic acid; while the other part, being deoxygenized in favour of the former, is converted into the combustible substance called alcohol." Ibid. p. 196.

† The spiritous or intoxicating quality of all fermented liquors is owing to the alcohol they contain, whether it be malt liquor, wine, or spirits.

Endeavour to recollect the different properties of charcoal, which yon have enumerated in this chapter.

Charcoal appears to be indestructible by age; it is not in the least altered by the most intense heat, if heated in *closed* vessels; when burnt in atmospheric air it becomes converted into carbonic acid gas; it is a valuable antiseptic; it is the basis of all vegetables; it is one of the component parts of wax, oils, gums, and resins: and from its affinity to oxygen it has the property of decomposing many substances in which oxygen constitutes a material part.

How did chemists become acquainted with all these properties of charcoal?

Formerly, nothing was known of charcoal but its indestructibility and its antiseptic qualities. The other peculiar and surprising properties of charcoal were reserved for the discoveries of the present age; for these we are most especially indebted to the labours and genius of Black‡, Priestley§, Cavendish, Lavoisier, Guyton, Tennant, and Berthollet, and to the gradual development of the present improved system of chemistry.

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‡ In the year 1755 Dr. Black discovered the acid gas which is thrown off from fermented liquors and from mild calcareous earth. He called it *fixed* air.

§ Dr. Priestley explained the effect of charcoal in decomposing nitrous acid, examined the gas that is thrown off in this decomposition, and pointed out the necessity of distinguishing

What reflections naturally present themselves on the consideration of the various properties of charcoal and the other simple combustibles?

This subject, when considered in all its connections, is calculated to produce the most profound admiration; and serves to convince us of the unbounded comprehension of that Divine mind, which, in the act of creation, could foresee and appoint such important effects to result from the combinations and changes of the most inodorous and insipid substances. We also learn, that all the works of the Creator are perfect; and perceive with astonishment, that they are composed of elements which are in themselves incapable of destruction*.

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the different gases from common air; for which the Royal Society awarded him an honorary prize.

In the years 1766 and 1767 Mr. Cavendish published papers in the Philosophical Transactions on the nature of elastic fluids, in which he announced that he had produced fixed air by the burning of charcoal. This assurance called the attention of all chemists to that surprising substance, and was the forerunner of the many discoveries which have since been made respecting its properties, &c.

Lavoisier pointed out the nature of the action of charcoal in reducing metallic oxides; investigated the nature of the combustion of the diamond; announced the exact quantity of carbon in carbonic acid; and the production of carbonic acid by the decomposition of water with ignited charcoal.

* See Additional Notes, No. 25 and 37.

CHAP. X.

OF METALS.

What are the characteristics of the metals?

The general characters of metals are, great specific gravity[*], lustre, opacity, fusibility, malleability, and ductility; but some metals are neither malleable nor ductile.

How are the metals procured?

They are generally taken from the bowels of the earth[†], in a state of combination either with

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[*] Metallic substances have a much greater specific gravity than all other bodies. That of the *heaviest* of the earthy bodies, sulphate of barytes, is only 4.4, not 4½ times heavier than water; whereas tin, the *lightest* of all the metals, except tellurium, is 7.291, or more than 7 times heavier than water.

[†] Metals are generally found in mountainous countries, in such as form a continued chain, but the metallic part of a mountain usually bears but a small proportion to its whole contents. Granite rocks seldom contain any metallic ores.

It is deserving of notice, that if minerals had been placed on the *surface* of the globe, they would have occupied the greatest part of the earth, and would have prevented its cultivation. Their being deposited *below* is a proof of management and design worthy of that Being who could furnish so great a variety of this class of bodies.

other metals[*], with sulphur, oxygen, or with acids[†], though a few of them have occasionally been found in a state of purity[‡].

By what methods are the metals purified from these substances?

The metals are purified from their ores by various means; such as washing, roasting, fusion[§], &c.; but the method must always be regulated by the nature of the ore to be assayed[||].

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[*] When metals are found combined with other metals they are called native alloys.

A table of the orders and the genera of the ores of metals may be seen in Dr. Thomson's Chemistry, vol. iv. 19.

[†] The sulphuric, muriatic, phosphoric, and carbonic acids are those which are generally found in combination with metals.

[‡] Among those metals which most frequently occur in the *metallic* state may be ranked quicksilver. In Bishop Watson's Chemical Essays mention is made of such a mine in this country, viz. at Berwick in Northumberland, in the midst of that town; and Mr. Hume, a native of that place, assures me that he was an eye-witness to this fact.

[§] The analysis of metallic ores in the great, is always performed by fire, and this is called the *dry* way; but the more accurate analysis is effected by means of various chemical reagents which modern chemistry has applied to that purpose, and is termed the *moist* way. Before the time of Bergman every kind of analysis of minerals was conducted by fire: he was the first chemist who resorted to the method of solution in acids, which is easy, simple, and effectual.

[||] Those who wish to investigate this subject may find ample information in Schlutter's work on Mineralogy; in Henkel's Pyritologia; in Cramer on Metals; in Kirwan's Mineralogy;

How many metals are there?

There are twenty-seven distinct metals, which possess properties very different and distinct from each other¶.

How are the metals classed by modern chemists?

They are divided into two classes. The one contains the malleable, the other the brittle, metals. This last class is sometimes subdivided into two others, viz. those which are easily, and those which are difficultly, fused.

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and in Klaproth's Essays. Some general ideas on the subject may be collected from a well-written paper of Dr. Thomson's, in his System of Chemistry, vol. iv. 174.

¶ For a knowledge of most of the metals, we are indebted to the more perfect modes of analysis which modern chemistry has afforded. The ancients were acquainted with only seven of these metals. The properties of these were tolerably well known to the early chemists, who acquired their knowledge from the alchemists. These infatuated people tortured silver, mercury, copper, iron, tin, and lead, in every way they could devise, in order to convert them into gold. Alchemy was probably introduced into Europe by the crusaders, whose minds were prepared for the reception of any delusion. In all likelihood they picked up the idea of the transmutation of metals on their return from Palestine; and as error generally operates more powerfully than truth with such fanatics, they deluged their native country with these absurdities. The vain and conceited Paracelsus, a Swiss physician, was one of the last of the alchemists. He announced to the world that he had discovered a medicine, which would render man immortal: but worn out by his debaucheries and excesses, he gave the lie to this assertion; for he himself died in the year 1534, at the age of 41.

In the reign of Henry IV. an act was passed to make it felo-

How many malleable metals are there?

Ten; viz.

1. Gold[*],
2. Platina,
3. Silver,
4. Mercury,
5. Copper,
6. Iron,
7. Tin,
8. Lead,
9. Nickel,
10. Zinc.

How many brittle metals are there?

There are thirteen metals in this class which are neither malleable nor ductile[†].

Which are the easily fusible of the brittle metals?

There are four fusible brittle metals; viz.

1. Bismuth,
2. Antimony,
3. Tellurium,
4. Arsenic.

Which are the brittle metals that are fused with difficulty?

There are nine of these metals; viz.

1. Cobalt,
2. Manganese,
3. Tungsten,
4. Molybdenum,
5. Uranium,
6. Titanium,
7. Chromium,
8. Columbium,
9. Tantalium[‡].

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ny to transmute metals. This act was repealed in consequence of the suggestions of Mr. Boyle, who was aware of its absurdity.

[*] Of these metals, the three first have been called noble or perfect metals; because they stand the most intense heat of our furnaces without suffering oxidizement, or any diminution in their weights.

[†] Owing to the brittle nature of these metals, such of them as were formerly known were called *semi-metals;* but this distinction, as it conveys erroneous ideas, is now generally laid aside.

[‡] In this enumeration I have purposely omitted the four

It will be necessary to consider each of these metals separately; therefore, what is the nature *of gold?*

Gold is the heaviest of all the metals, except platina; it is not very elastic, nor very hard; but it is so malleable and ductile, that it may be drawn into very fine wire, or beaten out into leaves thin enough to be carried away by the slightest wind§.

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metals found in the ore of platina, as their properties have not yet been sufficiently examined; and it is possible that they may be merely alloys of other metals. What is known respecting them, may be seen in the third volume of Murray's System of Chemistry, p. 169 to 197.

§ Dr. Black has calculated, that it would take fourteen millions of films of gold, such as is on some fine gilt wire, to make up the thickness of one inch; whereas 14 million leaves of common printing paper make up near $\frac{1}{4}$ of a mile. Vol. ii. 654. According to Fourcroy, the ductility of gold is such, that an ounce of it is sufficient to gild a silver wire more than thirteen hundred miles long.

Such is the tenacity of gold, that a wire $\frac{1}{16}$th of an inch in diameter will support a weight of 500 pounds without breaking.

Gold melts at 32° of Wedgwood, and if pure, is of a beautiful green colour when in fusion. By means of a powerful lens it may be volatilized.

Gold becomes much harder by a union with a small quantity of copper.

Gold leaf, thrown into oxygenized muriatic acid gas at the temperature of 70° or 80°, takes fire and burns with great brilliancy.

Fulminating gold is made by diluting a saturated solution of gold with three times its measure of distilled water, and precipitating the oxide by solution of ammonia *gradually* added.

Where is gold found?

Gold is found in Peru and in some other parts of the world. It generally occurs in a metallic state, and most commonly in the form of grains*.

The precipitate, when dried on a filter, forms this fulminating powder, which detonates by heat, or friction. A shocking account is related by Macquer, of a person losing both eyes, by the bursting of a phial containing fulminating gold, at the house of Baumé, and which exploded by the friction of the glass stopper against a minute quantity that adhered unobserved to the neck of the bottle. This accident ought to deter every one from making experiments with this dreadful compound.

Gold may be known from all other metals by its bright yellow colour, and its weight. Its specific gravity is 19.3; when heavier it must be combined with platina; when lighter, and of a deep yellow colour, it is alloyed with copper; if of a pale colour, with silver.

This noble metal may be detected when in solution, by green sulphate of iron: this precipitates it of a brown colour, which soon changes to the colour of gold.

* Gold frequently occurs in the ores of other metals, but it is chiefly found in the warmer regions of the earth. It abounds in the sands of many African rivers, in South America, and in India. Several of the rivers in France contain gold in their sands. It has also been discovered in Hungary, Sweden, Norway, and Ireland. Near Pamplona, in South America, single labourers have collected upwards of 200*l.* worth of wash-gold in a day. In the province of Sonora the Spaniards discovered a plain fourteen leagues in extent, in which they found wash-gold at the depth of only 16 inches; the grains were of such a size that some of them weighed 72 ounces, and in such quantities, that in a short time, with a few labourers, they collected 1000 marks (equal in value to 31,219*l.* 10*s.* sterling), even without taking time to wash the earth that had been dug.

What is the effect of oxygen *upon gold?*

Gold has so little affinity for oxygen, that it cannot be oxidized like the other metals; though this may be effected by amalgamating it with mercury, and applying heat†.

They found one grain which weighed 132 ounces. This is deposited in the Royal Cabinet at Madrid, and is worth 500*l.* Dr. Black, ii. 694.

The native gold found in Ireland was in grains, from the smallest size up to between two and three ounces. Only two grains were found of greater weight, one of which weighed five, and the other 22 ounces. See Phil. Trans. for 1796.

Gold mines were formerly worked in Scotland, and indeed now, grains of this metal are often found in brooks in that kingdom, after a great flood. It has been said, that at the nuptials of James V., covered dishes, filled with coins of *Scotch gold,* were presented to the guests by way of dessert.

Some of the French chemists assert that they have absolutely discovered gold in the ashes of vegetables.

† Gold has generally been thought susceptible of two degrees of oxidizement; the purple, and the yellow oxide; but neither of them is ever fouud native. See a note on metallic oxides and the formation of metallic salts, in chap. ii. under the 14th question.

It was formerly imagined that gold could not be oxidized by atmospheric air, even in the highest temperature: it has however been proved, that the heat produced by an electrical or galvanic discharge is sufficient to effect it, and to convert the whole of the metal to the *purple* oxide.

According to Fourcroy, gold and silver may be oxidized by triturating them in a mortar with saliva. This method is frequently made use of for oxidizing mercury. Saliva has a great affinity for oxygen. Nature seems to have endowed it with

What salts *of gold are there?*

There is only one salt of this metal that is much known to chemists, viz. the *muriate of gold*[*], which is obtained in small crystals, and is very soluble in water. Many other salts may

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this property, that it may absorb oxygen from the air to impart it to the food.

"If gold and silver should, when heated with other metals, undergo a slight degree of calcination by such a process, a stronger heat alone makes them immediately resume their pure and metallic form. The allusion therefore to this quality of the precious metals, to illustrate the triumph of a good heart over misfortune, is peculiarly beautiful; and as this is to be found in the book of Job, the discovery of the oxidizement and reduction of these metals must be very ancient."

The attraction of gold and silver for oxygen is so slight, that the rays of the sun alone will deoxidize the oxides of these metals.

The oxides of gold may be reduced by hydrogen gas, or sulphurous acid gas. If white satin ribbon, or silk, be moistened with a diluted solution of gold, and, while moist, exposed to a current of either of these gases, the metal will immediately be reduced, and the silk become gilt with a regular coat of gold. In this way any ornamental figures may be laid upon silk, the gilding of which will be very permanent. For the rationale of this process consult "Mrs. Fulhame on Combustion," to whom we are indebted for the idea.

[*] This salt is formed by dissolving gold in nitro-muriatic acid, and leaving the solution at rest for the salt to crystallize. In this process the nitric acid affords oxygen to the metal; and as the metal becomes oxidized the oxide is dissolved by the muriatic acid. Nitro-muriatic acid and oxygenized muriatic acid are the only acid solvents of this metal. A solution of muriate

be formed with this metal, but nothing at present is known either of their properties, or uses[†].

What are the uses *of gold?*

Gold is used for jewellery, for plate, and for current coin; but for these purposes it is generally alloyed[‡]. It is employed in various ways

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of gold, when concentrated by evaporation, yields beautiful yellow crystals not unlike *topazes.*

If ether be added to a solution of muriate of gold, the gold will leave the acid, and float upon its surface, combined with the ether. This ethereal solution has lately been used by Mr. Stodart and Mr. Savigny for defending their lancets and other surgical instruments from injury by a damp atmosphere. See Nicholson's Journal. It was formerly used in medicine under the name of *potable gold.* In those days of credulity it was generally prescribed to all patients who could furnish the apothecary with gold enough to make a sufficient quantity of the medicine to ensure a cure. The account which old Glauber gives of this celebrated panacea at the end of his "Treatise on *Philosophical Furnaces,*" 1651, page 393, will afford the reader some entertainment.

[†] As there are thirty-two acids, each of which is probably capable of uniting with each of the metals, the number of metallic salts that may be formed by art will amount to many hundreds: but in this elementary work, only those most known will be noticed; particularly the native salts, as these are the most interesting, and will be most easily remembered. In order to form this part of the chapter, I shall avail myself chiefly of Dr. Thomson's account of these bodies.

[‡] Gold, employed in jewellery, is generally alloyed with copper. What is called pale gold is alloyed with silver. See an interesting paper on the various alloys of gold, by Charles Hatchett, esq. in Phil. Trans. vol. xciii. 43.

Standard gold of Great Britain is twenty-two parts pure gold, in the arts*. Gold is also used to spread over other metals to preserve them from tarnishing or rusting, as gold does not become oxidized by exposure to atmospheric air †.

What is the origin *of silver?*

Silver is found in various parts of the world in a metallic state ‡; also in the states of a sulphuret, a salt, and an oxide §.

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and two parts copper; it is therefore called gold of "twenty-two carats fine."

* "In France they grind leaf gold, or the clippings of leaf gold, with honey, and then put it into muscle shells; this they call gold in powder, or in the shell. This gold, so prepared, is used for painting in miniature." *Monsieur Pomet's history of drugs.* Grinding leaf gold with honey, is now commonly practised by some artists in this country.

† Gold is also used in a state of solution, for staining ivory and ornamental feathers. It gives a beautiful purple red, which cannot be effaced: even marble may be stained with it. The nitro-muriatic acid is the menstruum used for this purpose. The potters dissolve gold in this way, to be applied to the common kind of porcelain. Bismuth or zinc will precipitate gold from this solution. Tin will precipitate it of a beautiful purple, called the *purple precipitate of Cassius.* This also is used by the potters in printing on porcelain. Sulphuret of potass will likewise dissolve gold. Some have thought that Moses made use of this process to render the calf of gold, adored by the Israelites, soluble in water. Stahl wrote a long dissertation in order to prove that this was the case. See Additional Notes, No. 29.

‡ Silver was used in commerce eleven hundred years before the foundation of Rome. Genesis xxiii. 16.

§ Native silver is found chiefly in the mines of Potosi. Sul-

What is the nature *of silver?*

Silver is a heavy, sonorous, brilliant, white

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phuret of silver occurs in the silver mines of Germany, Hungary, Saxony, and Siberia. Oxides of silver are also common in some of the German silver mines. Silver has lately been found in a copper-mine in Cornwall. See Mr. Hitchen's paper in Philosophical Transactions, vol. xci. 159. Most of our lead-mines also afford it, particularly some of the lead-mines in Scotland. In the county of Antrim in Ireland, there is a mine so rich, that every thirty pounds of lead-ore is said to produce one pound of silver. "In the museum of the Academy of Sciences at Petersburg, is a piece of *native* silver from China, of such fineness, that coins have been struck from it, without its having passed through the crucible." Storch's Picture of Petersburg, p. 330.

By the silver which was procured from the lead-mines in Cardiganshire, sir Hugh Middleton is said to have cleared two thousand pounds a month, and that this enabled him to undertake the great work of bringing the New River from Ware to London. In 1637, a mint was established at Aberystwith for coining Welsh silver. Bishop Watson.

Aristotle says, that some shepherds discovered the method of working the silver-mines of Spain; for, having occasion to clear a quantity of land by burning down the wood, they found fused silver produced by the operation of the fires.

It is owing to the spirit which the promulgation of chemical science has diffused among the landholders, that a silver-mine has been discovered in Cornwall, which has been worked for 20 years past with advantage.

"Nature, profusely good, with wealth o'erflows,
And still is pregnant, tho' she still bestows."

Blacklock.

It may be ascertained whether an ore contains silver, by pulverizing it and dissolving it in nitric acid, and afterwards metal*; exceedingly ductile, and of great malleability and tenacity. It possesses these latter properties in so great a degree, that it may be beaten into leaves much thinner than any paper†; or drawn out into wire as fine as a hair, without breaking.

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adding a little muriatic acid. Should it contain any silver, the muriatic acid will instantly combine with the whole of it, and precipitate it from the nitric solution in white flakes of muriate of silver. In order to know the proportion of silver in any given quantity of ore, collect this precipitate on a filter, heat it red, and weigh it accurately. Every 100 grains of this precipitate contains 73 grains of pure silver.

* The specific gravity of silver is 10.500. It is a very soft metal.

† Fifty square inches of silver leaf weigh not more than a grain. The silver wire used by astronomers is not more than half as thick as a fine human hair.

Silver melts at 28° of Wedgwood. In a temperature much higher it becomes volatilized.

Silver, gold, and platina require the heat of a powerful burning lens in order to put them in a state of combustion.

Silver has such an affinity for muriatic acid, that this acid is employed as a test for discovering silver in solution.

Silver readily combines with sulphur. According to Mr. Hatchett, those who rob the public by diminishing the current silver coin make use of the following method. "They expose the coin to the fumes of burning sulphur, by which a black crust of sulphuretted silver is soon formed, which, by a slight but quick blow, comes off like a scale, leaving the coin so little affected, that the operation may sometimes be repeated twice or thrice, without much hazard of detection." Philosophical Transactions, vol. lxxxviii.

What is the effect of oxygen *upon silver?*

Silver cannot be oxidized by atmospheric air, unless exposed to an intense heat; but the oxide of silver may be procured by dissolving the metal in an acid[‡], and then precipitating it by an alkali. There are two oxides of silver at present known, viz. the gray, and the white oxide[§].

To know when silver is pure, heat it in a common fire, or in the flame of a candle: if it be alloyed, it will become tarnished; but if it be pure silver, it will remain perfectly white.

[‡] The proper solvent for silver is the nitric acid, and, if the silver be pure, the solution will be colourless. If it contain gold, that metal will be precipitated as the silver dissolves. In dissolving dollars, I have sometimes seen a considerable quantity of gold precipitated. The Spanish dollars, I believe, always contain gold.

Silver is dissolved in nitric acid for forming the metallic tree. It is a pleasing experiment attended with very little expense. A metallic crystallization somewhat similar may be made by suspending a piece of zinc in a solution of acetate of lead. See Gren's Chem. vol. ii. 382. Thomson's Fourcroy, vol. ii. 487.

[§] Metals can combine only with one certain portion of oxygen, to give the first degree, and if that portion of oxygen be not present, the metal will not become oxidized. But when a metal is susceptible of two or more degrees of oxidizement, it becomes first oxidized with the smaller quantity of oxygen: after this, the new combination has a further attraction for oxygen, and the second degree of oxidizement takes place, &c.

Silver, when reduced to a liquid amalgam with mercury, is liable to be oxidized at the temperature of the atmosphere. This is owing to its having lost its natural coherence by that operation. The same may be said of an amalgam of gold.

What salts *are there of silver?*

The nitrate of silver* is best known; but in analysis the sulphate of silver is also a most useful test: many other salts of this metal† may likewise

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[*] This salt is kept in chemical laboratories as a test for the muriatic acid. When melted, and run in moulds, it forms the lunar caustic of the apothecary. When dissolved in water and left at rest, it crystallizes in brilliant transparent plates of different forms. Though the solution is as pale as pure water, it will stain the skin and other animal substances of an indelible black. It is employed to dye human hair; for staining marbles and jaspers; and for silvering ornamental work. This salt is the most powerful antiseptic known. One ounce of it dissolved in 12,000 ounces of water will preserve the water from putrefaction for ever, and it may any time be separated therefrom in a few minutes, by adding a small lump of common salt. Dr. Black, vol. ii. 661. An ingenious method of silvering ivory by the solution of this salt may be seen in Count Rumford's Phil. Papers, vol. i. 22.

A solution of nitrate of silver mixed with a little gum water forms the *indelible ink* used in marking linen.

[†] Hyperoxygenized muriate of silver has been used in making fulminating powder. If this salt be mixed with half its weight of sulphur, and struck slightly, it detonates with prodigious violence. The flash is white and vivid, and the silver is reduced. Dr. Thomson, ii. 539.

What is usually called *fulminating silver,* is made by a different process; but as it is so dangerous an article, it was thought best to omit giving directions for preparing it, in a work designed principally for the use of the young and the inexperienced. It is so dangerous, that a minute quantity only can be made at a time with safety, and even that could not be removed to a phial, without the utmost risque of shattering the glass by its detonation.

be formed. The muriate and the carbonate of silver are both found native[‡].

What are the uses *of silver?*

Silver is used chiefly for ornamental work, for domestic utensils[§], and for current coin; but for these purposes it is generally alloyed with copper[||], without which it would not have sufficient hardness to sustain much wear[¶].

How is platina *procured?*

Platina is found in grains, in a metallic state, at St. Domingo, and at Santa Fé in Peru[*].

[‡] Muriate of silver has been found crystallized in Saxony, and in South America. Carbonate of silver has been found in masses in Suabia.

[§] Pliny observes, that such was the luxury of the Romans, that it was simply reckoned a piece of elegance to consume in the ornaments of coaches, and in the trappings of horses, metals which their ancestors could not use even in drinking-vessels, without being astonished at their own prodigality. Nero and his wife shod their favourite horses with gold and silver. Bp. Watson, vol. iv. 188.

[||] Our standard silver is formed with 15 parts pure silver, and one part copper.

[¶] Silver is also used for plating other metals, for silvering dial-plates, &c. An account of these different processes may be found in Imison's School of Arts.

[*] Charles Wood was the first person who brought any of this metal to England. He brought it from Jamaica, in the year 1741; and published an account of his experiments upon it, in the Phil. Trans. for 1749 and 1750. Platina in the language of Peru means *little silver*.

The ore of platina contains no less than nine different sub-

What is the nature *of platina?*

Platina is the heaviest of all the metals*; is nearly as white as silver; and is difficultly fusible; but by great labour it may be rendered malleable, so as to be wrought into utensils like other metals †. It will resist the strongest heat

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stances, viz. silex, iron, lead, copper, platina; and four new metals, which are called iridium, osmium, rhodium and palladium. It is possible, however, as has been hinted before, that these latter may be merely alloys of other metals, as they have been found no where but in the ore of platina. Platina itself is indeed an alloy; for even after fusion, it is magnetic from the presence of iron. The properties of these new metals have as yet been but little investigated. For the methods of analysing the ore of platina, consult Dr. Wollaston's and Mr. Tennant's papers in the Philosophical Transactions, which are the best treatises on this metal.

Platina may be distinguished from all other metals by adding a solution of muriate of ammonia to a solution of the metal in nitro-muriatic acid, when a red-coloured precipitate will instantly appear. This is the only means yet known to discover when gold has been alloyed with this metal. Gold is generally known, if weighed hydrostatically, by its specific gravity; but if it be alloyed with platina some other test is necessary, as platina has a greater specific gravity than gold.

Some of the methods which have been employed to procure platina in a state of purity may be seen in Thomson's Chemistry, in the Phil. Trans., and other modern publications.

* The specific gravity of hammered platina is 23.66, which is more than double that of lead. It may always be known from other metals by this superior specific gravity, it being the heaviest body in nature.

† Mr. Knight was one of the first of the modern chemists

of our fires without melting ‡; and, like iron, is capable of being welded when properly heated.

What is the effect of oxygen *on platina?*

The oxygen in atmospheric air has no effect upon platina §, unless when assisted by an intense heat; but the oxide may be procured by dissolving the metal in nitro-muriatic acid, and precipitating it by an alkali ||.

What salts *are there of platina?*

A variety of salts may be formed with the

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who pointed out a way to render this metal malleable. See his paper in Philosophical Magazine, vol. vi. 1. Another method to accomplish this end has been published by Mr. Tilloch, in the twenty-first volume of the same work.

Platina has been drawn into wire less than the two thousandth part of an inch in diameter.

‡ The strongest of the pure mineral acids has no effect upon this metal, if employed separately; neither has the strongest fire, unless it be urged by a stream of oxygen gas. It may, however, be melted by a burning lens, or dissolved in oxygenized muriatic acid, or nitro-muriatic acid. If mixed with arsenic, and then exposed to a great heat, it fuses readily. By putting a platina wire into the flame produced by the combustion of mixed hydrogen and oxygen gases, Dr. Thomson caused it to burn with all the brilliancy of iron-wire, and to emit sparks in abundance.

§ On account of this property, as well as its hardness, it has been recommended for the fabrication of national standard weights.

|| This metal may also be oxidized by the electric spark, or by heating it with nitre. The latter method was introduced by Mr. Tennant. See Philosophical Transactions for 1797. The oxide, which is of a yellow colour, consists, according to

oxide of this metal; but none of them have yet been brought into much use *. No salt of platina has yet been found native.

What are the uses *of platina?*

Platina has hitherto been chiefly used for chemical utensils, such as crucibles, spoons, &c.†,

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Mr. Chenevix, of 87 parts metal and 13 of oxygen. Native oxide of platina is not known.

Proust says, that when platina is combined with other metals it oxidizes more easily than has hitherto been believed. Annales de Chimie, tome xxxviii.

* In order to form any salt with this metal, the platina must be previously dissolved in nitro-muriatic acid or oxygenized muriatic acid, these being the only menstrua that will act upon it. And in making the nitro-muriatic acid, three parts of muriatic acid should be mixed with one part of nitric acid; Proust having determined that this mixture dissolves the largest proportion of the metal. A solution of any other salt is then to be added, and by double affinity the new salt required may be obtained. Thus a solution of phosphate of soda would probably give a phosphate of platina.

† The important uses to which this precious metal may be applied can be easily conceived, when it is considered that it unites the indestructibility of gold to a degree of hardness almost equal to that of iron; that it resists the action of the most violent fire, and also of the most concentrated acids. Aware of these properties, a chemist in the neighbourhood of London has been induced to expend several hundred pounds, in the fabrication of a single utensil for rectifying sulphuric acid. Vessels of capacity made with this metal must always come extremely dear, as it is necessary to solder them with gold. There is one disadvantage attending the use of this metal for chemical purposes, which is, that it is corroded by caustic alkalies.

and to make specula for telescopes. It has also been beaten into leaves, and applied to porcelain in the manner of leaf gold [‡]. Its oxide is used in enamel painting [§].

Indeed crucibles of platina have been eroded by analysing minerals in them which have contained some of the neutral salts.

[‡] A very neat method to cover other metals with platina was lately discovered by Mr. Stodart, who found that, like gold, it may be taken up from its solution by sulphuric ether. See Nicholson's Journal for the year 1805.

It is said that M. Strauss has, after many experiments, succeeded in applying platina to the coating of copper with as much ease as the common operation of tinning. The durability of this metal, and its resistance to acids and saline matters, will render this a most valuable discovery.

An alloy of copper with this metal is likely to prove very valuable, as it is malleable and ductile, is susceptible of a fine polish, and receives no tarnish of its lustre by exposure to the air.

I am informed that crude platina melted with copper and silver affords a compound that oxidizes but little by muriatic or nitric acid, and which when drawn into wire is highly elastic, and very useful for springs that are designed to be exposed to the action of the atmosphere. An alloy of this kind is employed in the manufacture of Mr. Stansbury's new patent locks, and is likely to give them great durability.

By melting 15 parts of gold with one part of purified platina, Mr. Hatchett produced a yellowish-white alloy, extremely ductile, and very elastic; so much so, that he is of opinion it might be used with great advantage in making watch springs.

[§] Klaproth proposed the use of platina in enamel painting, instead of silver, which is liable to tarnish. Platina has not this inconvenience, and when intermixed with figures of gold has a beautiful appearance. Besides, various coloured alloys

Where is mercury found?

Mercury is brought to Europe from the East Indies, and from Peru*; but it is found in greater abundance at Almaden†, in Spain, where it is extracted from the ore by distillation‡.

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may be formed by the union of the two metals so as to produce a great variety of shade of colour. Directions for using platina in this way may be seen in the 17th vol. of the Philosophical Magazine.

* The quicksilver mine of Guança Velica, in Peru, is 170 fathoms in circumference, and 480 deep. In this profound abyss are seen streets, squares, and a chapel, where religious mysteries on all festivals are celebrated. Millions of flambeaux are continually burning to enlighten it. The mine generally affects with convulsions those who work in it. Notwithstanding this, the unfortunate victims of an insatiable avarice are crowded all together, and plunged *naked* into these abysses. Tyranny has invented this refinement in cruelty, to render it impossible for any thing to escape its restless vigilance.

> "Thus in the dark Peruvian mine confin'd,
> Lost to the cheerful commerce of mankind,
> The groaning captive wastes his life away,
> For ever exil'd from the realms of day;
> While, all-forlorn and sad, he pines in vain
> For scenes he never shall possess again." FALCONER.

† In the year 1717, there remained above 1200 tons of quicksilver in the magazines at Almaden, after the necessary quantity had been exported to Peru for the use of the silver mines there.

The quicksilver mines of Idria, a town in the circle of Lower Austria, have constantly been wrought for 300 years, and are thought upon an average to yield above 100 tons of quicksilver annually. Bp. Watson.

‡ Mercury is found also in Hungary and China; it occurs

What is the nature of mercury?

Mercury, in the temperature of our atmosphere, is a fluid metal §, having the appearance of melted silver: in this state it is neither ductile

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most commonly in argillaceous schistus, limestones, and sandstones. It is found in Sweden amalgamated with silver, and, frequently, combined with sulphur. Running mercury is found in globules, in earths and stones, in America, and collected from the clefts of the rocks there. Cinnabar, or sulphuret of mercury, is generally found also in those countries which produce the fluid metal. To extract the metal from the cinnabar, this ore is mixed with quick-lime and then submitted to heat. The lime combines with the sulphur, and the mercury, which sublimes from the mixed mass, is collected in receivers. An account of the whole process may be seen in the Memoirs of the French Academy for 1776. See also Note, page 352.

According to Proust, mercury is found mixed with all marine salt; and the muriatic acid of commerce contains mercury in the state of corrosive sublimate, arising from the mercury naturally mixed with sea-salt. Nicholson's Journal, vol. iii. 4to, 375.

§ We see mercury always in a *fluid* state, because it is so very fusible that a small portion of caloric is able to keep it in a state of fluidity; but it is as perfectly opaque as other metals. All metals require different portions of heat to fuse them. Lead melts with so little heat, that when first melted the hand may be plunged in it without occasioning pain; whereas gold requires the heat of 32° of Wedgwood to melt it, and platina cannot be fused by the strongest heat of our best furnaces. Mercury, when submitted to a sufficient degree of cold, is similar in appearance to other metals, and may be beaten out into plates. It has been determined that 39 degrees below zero nor malleable; very volatile when heated*; extremely divisible; and is the heaviest of all the metals except platina and gold †. It readily combines with several of the other metals, and forms with them what are called amalgams ‡.

What effect has oxygen *upon mercury?*

Mercury does not combine with oxygen § in

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of Fahrenheit's thermometer is the point at which the congelation of mercury takes place. At the poles quicksilver would be uniformly solid.

In the winter of 1799, Mr. Pepys froze 56 pounds of mercury into a solid and malleable mass. A minute account of the process by which he effected it may be seen in the Philosophical Magazine, vol. iii. page 76.

[*] Mercury is a substance so volatile that it may be distilled like water. It is sometimes purified in this way from a mixture of other metals, it being often adulterated with lead and bismuth. It is also so elastic when in a state of vapour, that it is capable of bursting the strongest vessels. There is no better way of ascertaining the purity of mercury than by mixing it with an equal weight of iron-filings, and submitting it to distillation.

[†] According to Mr. Biddle, the specific gravity of mercury at 47 degrees above zero is 13.545; but when frozen into a solid at 40 *below* zero, 15.612.

[‡] Mr. Chenevix has pointed out a singular anomaly in the amalgamation of platina. The specific gravity of the amalgam he states at only 11. 5, whereas the specific gravities of the metals from which it is formed are not less than 13 — 5 and 21. No one has hitherto given any satisfactory explanation of this curious circumstance.

[§] Mercury will not burn either in atmospheric air, in oxygen gas, or in oxygenized muriatic gas. The same may be said of the ordinary temperature of the atmosphere, even when an extended surface is exposed; but if heated to about 600° of Fahr. it gradually becomes oxidized. Acids are generally employed to oxidize it ||.

What salts *are there of mercury?*

There is a great variety of mercurial salts; but the acetate, the sulphate, the nitrate, and the muriate of mercury are best known. The latter is found native in the Palatinate¶.

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gold and silver; which has induced Dr. Thomson to exclude these three metals from the class of combustibles. See his Essay on Combustion, in Nicholson's Journal.

[||] Mercury may readily be oxidized by dissolving it in nitric acid, and then precipitating it from its solution by the addition of a pure alkali, or by exposing the solution to a proper degree of heat to expel the remaining acid.

The beautiful scarlet pigment called *vermilion* is prepared from mercury. It is the red sulphuretted oxide of mercury. Europe has hitherto been furnished with it by the Dutch manufacturers, and of greater beauty than any which has been procured from other markets; though it is said that even this article is inferior in splendour to that which is manufactured in China. What is imported from thence comes in small papers, and is nearly of the colour of fine lake.

[¶] Several salts are formed by art with this metal for medicinal purposes; viz. *Keyser's pill,* which is an acetate of mercury; *Turbith mineral,* a sub-sulphate of mercury; *Red precipitate,* or oxide by means of the nitric acid; *Calomel,* or mild muriate of mercury; and *Corrosive sublimate,* which is an oxygenized muriate. Besides these there is a preparation called *Precipitate per se,* which is a true oxide of the metal; and

What are the uses *of mercury?*

Mercury is used in large quantities for silvering mirrors, for water gilding*, for making barometers and thermometers, and in the manufacture of vermilion. It has also various and important uses in medicine†.

Ethiops mineral, and *Cinnabar*, which are both combinations of mercury with sulphur.

One of the most valuable of the above salts is *calomel*, which is made by triturating fluid mercury with corrosive sublimate, and then submitting the mixture to sublimation. As this medicine is much used in private families, and as dreadful consequences might ensue if it were improperly prepared, it ought to be generally known, that if it be not perfectly insipid to the taste, and indissoluble by long boiling in water, it contains a portion of oxygenized muriate of mercury, or corrosive sublimate, and is consequently poisonous.

[*] See Additional Notes, No. 29.

[†] A fulminating powder has also been made with this metal, which might be advantageously employed for blasting rocks, as its immediate force is much greater than that of gunpowder, though it does not extend so far. This is said to have been discovered by Mr. Howard, and is usually called "Howard's fulminating powder:" but it appears from a pamphlet I have lately seen, entitled *Miscellanea verè utilia*, by Boyle Godfrey, published many years before this discovery, that this same powder had then actually been prepared; and that, as the author's attention was chiefly occupied with the nitrous ether, he luckily escaped the danger of operating upon the rejected fulminating mercury.

In South America mercury is used to separate gold and silver from the extraneous matter found with those metals. By triturating the mass with mercury, the gold and silver become

How is copper *procured?*

Copper is found in several parts of England and Wales, particularly in Cornwall, and in the isles of Man and Anglesea. It is an abundant metal, and has been raised in various other parts of the world‡.

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amalgamated with it; and afterwards this amalgam is submitted to heat, when the mercury sublimes, and the perfect metals are left in a state of purity.

Several of the uses of mercury were known to the ancients. Theophrastus, an ancient Greek philosopher, who wrote about 300 years before Christ, was acquainted with it, and knew how to work it so as to form vermilion.

‡ Copper mines have been worked in China, Japan, Sumatra, and in the north of Africa. Native copper is found in Siberia crystallized in cubes. The copper pyrites found in Cornwall and upon several parts of the English coast are *sulphuret* of copper. Anglesea yields more than twenty thousand tons of copper annually. The vein of metal is more than 70 feet thick. Dr. Black, vol. ii. 647. See Additional Notes, No. 32.

In the museum of the Academy of Sciences at Petersburg is a piece of native malleable copper of extraordinary magnitude, found on the copper-island lying to the east of Kamtschatka. Storch's Picture of Petersburg, page 319.

Native oxides of copper are found in Cornwall and in South America. Carbonate of copper occurs as a natural production, in two varieties called *malachite* and *mountain green*.

I am informed that a large copper mine has been worked for some time in the state of New Jersey in America, and that the ore raised there is brought to this country to be smelted. The sulphate of copper is also found of a very rich quality in the state of Connecticut. The stream destroys vegetation in

Of what nature *is copper?*

Copper is of a red colour, very sonorous* and elastic†, and the most ductile of all the metals, except gold.

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its course; and where it settles in places near the spring, large lumps of metallic salt are collected. The practice of precipitating the metal by means of iron is also adopted in the United States.

Copper mines have not been worked in England above 150 years. Before that period, whenever the workmen met with copper ore in the tin mines of Cornwall, they threw it aside as useless, no one at that time knowing how to reduce it to a metallic state. To chemical science, therefore, we are entirely indebted for such an ample supply of this valuable metal. ~~See Additional Notes, No. 33.~~

Copper was the only money used by the Romans till the 485th year of their city, when silver began to be coined. In Sweden, houses are covered with this metal.

When miners wish to know whether an ore contains copper, they drop a little nitric acid upon it: after a little time they dip a feather into the acid and wipe it over the polished blade of a knife; and if there be the smallest quantity of copper in it, the copper will be precipitated on the knife. A better mode of ascertaining the fact, perhaps, could not be devised.

Copper will not burn so easily as iron; which is evident from its not striking fire by collision like iron. On this and other accounts this metal has been substituted for iron in the machinery which is employed in gunpowder mills.

Copper does not enter into combustion till it has acquired a

* It is on account of this property that copper is chosen for making trumpets and other musical instruments.

† Copper, on account of its elasticity, is used by rope-dancers, &c. A wire $\frac{1}{10}$th of an inch diameter will support near 300 pounds.

What is the effect of oxygen *upon copper?*

Copper will in some measure become oxidized by long exposure to atmospheric air, in which case its surface will be covered with the green oxide called verdigris‡. It is susceptible of many degrees of oxidizement §.

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heat more than sufficient to melt it. But if kept in a stream of oxygen gas, it will burn with a vivid blue flame.

Oxide of copper is soluble in ammonia, and precipitable from its solution by sulphuretted hydrogen.

‡ In domestic œconomy the necessity of keeping copper vessels always clean is generally acknowledged; but it may not perhaps be so generally known, that fat and oily substances, and vegetable acids, do not attack copper while *hot*; and, therefore, that if no liquid be ever suffered to grow *cold* in copper vessels, these utensils may be used for every culinary purpose with perfect safety.

Dr. Johnstone relates the shocking case of three men who died, after excruciating sufferings, in consequence of eating some victuals prepared in an unclean copper, on board the Cyclops frigate. Thirty-three other men became ill and were put upon the sick-list, at the same time and from the same cause. Essay on Poisons, page 102.

Dr. Percival gives an account of a young lady who amused herself while her hair was dressing with eating samphire pickle, impregnated with copper. She soon complained of pain in the stomach, and in 5 days vomiting commenced, which was incessant for two days. After this her stomach became prodigiously distended; and in nine days after eating the pickle, death relieved her from her sufferings. Medical Transactions, vol. iii. 80.

§ Copper beginning to be oxidized is brown and reddish; a little more oxygen renders it blue; whereas a perfect oxide of this metal is of a bright green.

What salts *of copper are there?*

There are a great many salts of copper; but those most used are, sulphate of copper*, acetate

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* Roman vitriol, much used by dyers and in many of the arts, is sulphate of copper. Fowling-pieces and tea-urns are browned by washing them with a solution of this salt. *Verdigris* is an acetate of copper. *Blue verditer*, much used in staining paper for hanging rooms, is a nitrate of copper combined with carbonate of lime. The beautiful grass green colour of the shops, called *mineral* green, is a muriate of copper. The colour known by the name of *Scheele's* green is an arseniate of copper. The colour called *Brunswick* green is a triple salt, formed with potass, copper, and the tartaric acid.

Sulphate of copper is frequently found in the streams of water in copper mines: these waters were suffered to run to waste, till an attention to chemical affinities taught the proprietors of the mines how to turn them to a good account. The quantity of salt which they contain is not sufficient to reimburse the expense of boiling it down to blue vitriol; but by throwing waste iron into these waters the salt becomes decomposed, and the copper is precipitated in a metallic form. This is owing to the sulphuric acid having a greater affinity for iron than it has for copper. In the isle of Anglesea this principle is turned to an advantageous account.

Bishop Watson relates, that the waters which issue from the copper mines in the county of Wicklow in Ireland, are so impregnated with sulphate of copper, that one of the workmen having accidentally left an iron shovel in this water, he found it some weeks after, so incrusted with copper, that he imagined it was changed into copper. The proprietors of the mines, in pursuance of this hint, made proper receptacles for the water, and now find these streams of as much consequence to them as the mines.

of copper[†]; nitrate, muriate, and arseniate of copper; and the tartrate of potass and copper. Besides these, which are generally formed by art, the carbonate, the arseniate, the muriate, the phosphate, and the sulphate of copper are found in a native [‡] state.

What are the uses *of copper?*

The uses of this metal are too various to be enumerated. Besides its employment to make vessels of capacity, and to sheathe the bottoms of ships, it is alloyed with zinc to make brass [§], and

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[†] An account of the process of making verdigris at Montpelier may be seen in Mons. Pomet's History of Drugs, page 338, or in Annales de Chimie, tom. xxv. 305.

Mr. Hume, of Long-Acre, has produced a very useful pigment by the combination of copper with the prussic acid. See Phil. Mag. vol. xx. 142.

[‡] The ores of copper, called *malachite*, and mountain green, are native carbonates of copper, as was before mentioned. The green sand brought from Peru is a native muriate of copper. A phosphate of copper, containing 30 per cent. of phosphoric acid, has been found near Cologne. The arseniate of copper occurs plentifully in the Huel Garland mine in Cornwall; and sulphate of copper has been found in some mineral waters.

[§] Brass is never made with pure zinc, but generally with calamine, which is a native oxide, or, rather, carbonate of zinc. Bishop Watson is of opinion that the *orichalcum* of the ancients was the same as our brass. Pliny says that the best mirrors were anciently made with a mixture of copper and tin; but that in his time those of silver were so common, that they were used even by the maid servants. These metallic mirrors were when combined with sulphuric acid forms Roman vitriol*. Its oxides are employed in enamel painting, and in the manufacture of several colours.

What is the origin *of iron?*

Iron is plentifully and universally diffused throughout nature, pervading almost every thing, and is the chief cause of colour in earths and stones. It may be detected in plants† and in animal fluids. It is found in great masses, and

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very much in request among the ancient nations. The Egyptian women, whenever they went to their temples, carried one of these mirrors in the left hand. A process for separating zinc from brass will be found in Ann. de Chim. tom. xxxviii.

* In order to make Roman vitriol, the copper is first oxidized by the following process: Plates of copper are heated red hot in an oven, by which means they become quickly covered with a crust of oxide, which separates as the plates cool; for the metal contracts much on cooling, though the oxide contracts but little, if at all.

Oxide of copper is used by the coloured-glass-makers. It forms a beautiful *green* glass.

Mr. Sage has shown that copper combined with phosphorus acquires the hardness of steel, is susceptible of the finest polish, and does not become altered in the air. Phil. Mag. vol. xx. 159.

Copper is used also in making princes-metal, gun-metal, bell-metal, tombac, and some other mixed metals.

† Iron has been found in metallic grains in strawberries. It is said that oak wood when dried contains one-twelfth of its weight of this metal.

in various states, in the bowels of the earth in most parts of the world ‡.

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‡ There is a great variety of iron ores (chiefly composed of the oxides of iron and clay), which have different names given them by the workmen, and are of very different qualities; for which consult Bergman, Kirwan, and others.

Native metallic iron has been found in Siberia and in Peru, in a state of malleability, and yet in such enormous masses as to preclude any supposition of their being the productions of art. Besides, they are found entirely insulated, and at great distances from any mountain, volcano, or bed of ore from whence they might have been supposed to be derived. They are so similar in their composition to the meteoric stones, that Mr. Murray and some others are of opinion that they have the same origin. La Place and Dr. Hutton suppose that these meteoric stones have been projected from a volcano in the moon.

"In the museum of the Academy of Sciences at Petersburg, is a mass of *native iron* twelve hundred pounds weight."

Some of the French chemists are of opinion that iron owes its origin to decayed plants and animals.

Iron is found in greater abundance than any other metal. In the northern parts of the world whole mountains are formed of iron ore, and many of these ores are magnetic. Of the English ores, the common Lancashire hematite produces the best iron. See Additional Notes, No 34.

In the great iron works, the ore, broken into small pieces and mixed with substances to promote its fusion, is thrown into the furnace; and baskets of charcoal or coaks in due proportion are thrown in along with it. See Note, page 168. A part of the bottom of the furnace is filled with fuel only. This being kindled, the blast of the great bellows is directed on it, and soon raises the whole to a most intense heat: this melts the ore immediately above it, and the reduced metal drops down through the fuel and collects at the bottom. The

What is the nature of iron?

Pure iron is soft and ductile*, and when dissolved has a sweet and styptic taste, and emits a peculiar smell when rubbed. It is attracted by the magnet, and has the property of becoming

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rest sinks down, to fill up the void left by the consumed fuel and metal: this, in its turn, comes next in the way of the bellows, and is also reduced. More ore and fuel are supplied above, and the operation goes on till the melted metal at the bottom, increasing in quantity, rises almost to the aperture of the blast: it is let out by piercing a hole in the side of the furnace, and then forms what are called *pigs* of cast iron. Dr. Black, vol. ii. 400.

The rationale of making iron from the ore is well explained by Dr. Thomson, in his System of Chemistry, vol. i. 156. See also an excellent paper by Mr. Collier, in the Manchester Memoirs, vol. v.

* An iron wire, only one-tenth of an inch in diameter, will carry 450 pounds without breaking. A wire of tempered steel of the same size will carry near 900 pounds. Black.

Iron is of a livid blueish colour, very hard, and the most elastic of all the metals. Its specific gravity varies from 7.6 to 7.8.

Iron becomes soft by heat, and has the capability of being welded to another piece of iron, both being sufficiently heated, so as to form one entire mass. No other metal possesses this singular property, except platina. Notwithstanding this, pure iron is nearly infusible. In order to effect the fusion of this metal, it is necessary to surround it with the fuel, and to urge the fire to the utmost possible pitch. Crude or pig iron is fused readily: hence, it may be cast into any form, and is employed in the fabrication of a vast variety of machinery and utensils.

itself magnetic †. It is fused ‡ with great difficulty, but it gives fire by collision with flint.

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† If a bar of iron be suspended for some time in a perpendicular position, it becomes magnetic. If friction be employed in a peculiar way, it quickly acquires strong magnetic powers. For particulars consult Cavallo's Elements of Natural Philosophy. The late Dr. Godwin Knight possessed a surprising skill in magnetism; being able, not only to communicate an extraordinary degree of attractive and repulsive virtue to his artificial magnets, but even to alter or reverse their poles at pleasure. This singular man refused every offer that was made to him for the discovery of his method, and, to the last, declared that the largest sum that could possibly be tendered, should not induce him to divulge it. Of course these curious and valuable secrets died with him.

The advantages which we derive from the magnetic property of iron are incalculable. To this astonishing property we are indebted for an instrument—the mariner's compass—by which man is enabled to traverse the ocean, to open a friendly or commercial intercourse with every quarter of the world, and to steer his course towards any particular country with the utmost accuracy and certainty.

" Tall navies *hence* their doubtful way explore,
And ev'ry product waft from ev'ry shore;
Hence meagre want expell'd, and sanguine strife,
For the mild charms of cultivated life." BLACKLOCK.

‡ Mr. Wedgwood fused some soft iron nails in a crucible at the heat of 154 of his scale. Sir George Mackenzie did not produce the same effect till his furnace acquired the temperature of 158°: cast iron melts at 130°.

Prussiate of potass is the usual test for iron. When added to a liquid which contains iron, it will cause a blue precipitate, if the iron has its full complement of oxygen; but if the iron is partially oxidized the precipitate will be gray. Succinate of ammonia will precipitate oxide of iron from its solutions.

Is iron always used in the state in which it is procured from the ore?

No: iron is employed in three states; viz. that of *cast* iron[*], *wrought* iron[†], and *steel*; each of which is of a different quality, and used for different purposes.

What constitutes the difference in these three kinds of iron?

Cast iron is the metal in its first state, rendered fusible by the combination of carbon and oxy-

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[*] To convert *cast* iron into *wrought* iron, the former is kept in a state of fusion for a considerable time, and by repeated stirring in the furnace, the oxygen and carbon which it contains form an union, and rise from the mass in the state of carbonic acid gas. As the carbon and oxygen thus go off, the iron becomes more infusible; it gets thick or stiff in the furnace; and the workmen know by this appearance that this is the time to remove it from the fire, and to submit it to the action of the hammer, or the regular pressure of large steel rollers, by which the remaining impurities are forced out, and the metal is rendered malleable, ductile, and totally infusible. In this state it is known in commerce by the name of bar iron. A considerable loss in weight, however, is sustained by this process; not only from the impurities, but from the surface of the iron oxidizing and falling off in scales while hammering.

[†] In purchasing wrought iron, the workmen distinguish two kinds which are both of very inferior value. They are called *hot-short* and *cold-short* iron. The former is a fusible metal, which possesses ductility when *cold*, but is so brittle when *heated*, that it will not bear the stroke of the hammer. The cause of this variety is not known. The latter kind is very malleable and ductile while hot, but the utensils made with it

gen[‡]. *Wrought* iron differs from the former, in being deprived of this carbon and oxygen, by continued heat and repeated hammering, which render the metal malleable[§]. *Steel* is made of wrought iron, by various processes, whereby the metal resumes a small portion of carbon, and acquires a capacity to receive different degrees of hardness[‖].

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are as brittle as cast iron when cold. Such iron contains a portion of *phosphuret of iron*, which Bergman believed to be a new metal, and called it *siderite*.

[‡] Cast iron which breaks of a *white* colour should be refused, as it contains a portion of phosphuret of iron.

[§] Though iron is deprived of part of its carbon and rendered malleable by hammering, *too much* hammering will deprive it of its malleability. Dr. Black was of opinion that this arises from the loss of a portion of its latent caloric by the operation, and that metals are malleable in proportion to the matter of heat which they contain in a latent state. Lectures, vol. i. 139.

[‖] Steel, like cast iron, contains carbon, but is divested of oxygen, which is always combined with the latter.

If a slender rod of wrought iron be plunged into cast iron in fusion, it will absorb part of the carbon and become steel. What is called *case-hardening* is a conversion of the surface of iron into steel.

Mr. Morveau exposed a diamond to intense heat, shut up in a small cavity in a piece of tough iron. When he opened the cavity he found the diamond entirely gone, and the iron around it converted into steel. Annales de Chimie, tom. xxxi. 328. This is one proof that the diamond is carbon, and shows that it is *pure* carbon, which combines with iron to form steel, and not charcoal, which is an oxide of carbon. The peculiar hard-

What is the effect of oxygen *upon iron?*

Iron has such an affinity for oxygen, that it will become oxidized merely by exposure to the air. The oxides of iron* are found in great plen-

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ness of steel is to be ascribed to its union with a portion of pure carbon or *diamond.*

It is no uncommon thing for jewellers to expose such diamonds as are foul, to a strong heat, imbedded in charcoal to render them clear; but in this process great care is taken to have a sufficient quantity of charcoal to exclude the atmospheric air, otherwise the intense heat would produce combustion.

Steel, by repeatedly heating and hammering it, may be converted into wrought iron.

A steel instrument may be known from one of iron thus: If a drop of nitric acid be let fall upon it, it will occasion a black spot if it be steel, but will not have this effect if it be wrought iron. The blackness is owing to the acid oxidizing the carbon of the steel, and converting it into charcoal.

Cast steel is manufactured in some parts of this kingdom with great secrecy; but it is now known that it may be made merely by fusing iron in an intense heat with carbonate of lime. Cast steel contains more carbon, and is more fusible than common steel.

As different tempers are given to all kinds of edge-tools, by the different degrees of heat to which they are submitted, what is now a very precarious operation, might be reduced to a certainty by means of a metallic bath of fusible metals, containing a thermometer, to show the degrees of temperature. A mixture of bismuth, lead and tin, will afford a compound that will continue fusible with the heat of boiling water. Mr. Stodart has long availed himself of this method in making surgical instruments.

* The chief distinction between *black* and *red* oxide of iron is, that the latter contains nearly twice as much oxygen in a

ty ready formed in the bowels of the earth. This metal, like most others, is susceptible of various degrees of oxidizement.

What salts *of iron are there ?*

The most useful salts of iron are those composed with the sulphuric, the nitric, the muriatic, and acetic acids; and these with some others

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given portion as the former. The scales, which are detached from forged iron by a high degree of heat, and which Dr. Priestley employed in several of his last experiments in America under the name of *finery cinder*, are in the state of the former. The iron contained in martial pyrites is in the state of an oxide combined with sulphur. The super-sulphuret of iron in this mineral is converted into *sulphate* of iron at the great copperas works, by exposing the pyrites to the air and rain for several months, in large beds prepared for the purpose. The sulphur decomposes the water which falls upon the beds, and is itself converted thereby into sulphuric acid, which combining with the iron forms the salt in question. This is afterwards extracted from the mass by lixiviation and crystallization. This process is carried on upon a large scale at Deptford, near London, where the united acidifying powers of air and water are well exemplified, and is worthy the notice of all who delight in contemplating the secrets of nature.

According to Mr. Chenevix, there are four oxides of iron, the first or least degree of oxidizement being white, and progressively to green, black and red, founded upon the different colours which minerals possess that contain iron. Others, however, think that this variety of colour results from the various combinations into which the two oxides of iron enter, difference of colour being a very uncertain mark of difference in the degree of metallic oxidizement.

are very essential to our manufactures*. The arseniate, sulphate, phosphate, chromate, and tungstate of iron, have all been found native †.

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[*] *Green vitriol*, which is of so much use in dyeing, in making hats, and in other manufactures, is a sulphate of iron, formed, as has already been described, by the decomposition of martial pyrites. The nitrates, muriates, and acetates of iron, are prepared by art for the use of calico-printers, who consume great quantities of these salts in a state of solution.

[†] The native arseniate of iron is found in Cornwall; native sulphate of iron occurs frequently with pyrites; *phosphate of iron* ready formed occurs frequently in bogs—it is called native Prussian blue; chromate of iron has been found in France and in Siberia; and tungstate of iron exists native in a mineral, found in Britain and elsewhere, called wolfram. The sparry iron ore is a carbonate of iron.

Phosphate of iron has been very lately introduced as an important and efficacious application in cancerous complaints. See one of the last numbers of the Medical and Physical Journal.

Carbonate of iron is commonly found in solution in chalybeate waters: such waters may be known by the dark orange-coloured film which generally appears upon their surface: the oxide of iron is rendered soluble by an excess of carbonic acid. This may be shown by adding a few grains of quick-lime to a small quantity of such water; the lime will combine with the carbonic acid, and the oxide of iron will be precipitated.

Besides the above, *carburet* of iron (usually called *black lead*) is found in several parts of the world. A combination of iron and silex also occurs native, and forms what is called *emery*; a substance very useful in the arts; and of which large quantities are found in the island of Jersey. It is employed by lapidaries, and by glass-cutters to cut glass and to stopper bottles for chemical and other purposes.

What are the uses *of iron?*

The uses of iron are innumerable; every thing we possess is manufactured by its means; it is the most useful substance in the world ‡. When

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Some of the ores of iron are used in their native state; such as the hæmatite, which is made into burnishers, &c.

Iron was in use in the time of Moses. Deut. iv. 20., viii. 9., and xviii. 5. The Greeks understood the method of tempering it. Homer describes the fire-brand dropt into the eye of Polyphemus, as hissing like hot iron immersed in water;

> "And, as when arm'rers temper in the ford
> The keen-edg'd pole-ax, or the shining sword,
> The red-hot metal hisses in the lake,
> So in his eye-ball hiss'd the plunging stake."
>
> Odyssey, book ix. 465.

‡ The property of *welding*, which, except platina, no other metal possesses, renders iron the most suitable of all others for every common purpose. It becomes soft by heat, and thus may be moulded by the hammer into any form, and united in as many parts as the workman pleases, without rivets or without solder.

Were it not for this peculiar quality of iron, many works of the utmost importance could never have been executed. The most stupendous fabric that I recollect to have ever read of, that was achieved by means of *welded* iron, is the Chinese *bridge of chains*, hung over a dreadful precipice in the neighbourhood of Kingtung, to connect two high mountains. The chains are twenty-one in number, stretched over the valley, and bound together by other cross chains, so as to form a perfect road from the summit of one immense mountain to that of the other.

Fourcroy says, iron is the only metal which is not noxious, converted into steel it is employed in various ways *, especially for edge-tools; all which are formed in part with this metal, from the ponderous pit-saw to the finest lancet †. Its oxides

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and whose effects are not to be feared. Indeed, its effects on the animal œconomy are evidently beneficial. For a detailed account of its various and important uses in medicine, consult Fourcroy's Elements, Thomson's edition, vol. ii. 466, and following pages.

The ancients had an idea that iron was poisonous, and that wounds made with iron instruments healed with difficulty. Hence, after the expulsion of the Tarquins, Porsenna stipulated with the Romans that they should not use iron except in agriculture.

* Good steel is much more ductile than iron; hence very minute instruments are generally made with it. A finer wire may be drawn from it, than from any other metal.

† The excellence of edge-tools depends upon the temper given to them by heat. This requires great skill and peculiar management. A valuable report on the art of making fine cutlery may be seen in Nicholson's Journal, 4to, vol. iv. 127.

Sulphate of iron is not only used by the hatters and dyers, but also in making ink, in the manufacture of Prussian blue, in preparing leather, and in forming colcothar for painters. Colcothar is nothing more than sulphate of iron calcined to redness. It not only makes a useful pigment, but is employed in polishing different kinds of metals. It is from the iron which it contains that a piece of an old hat is useful for the same purpose. The oxide of iron imparts its colour to a great variety of natural substances. It is the cause of the redness of common bricks; it gives colour to the cornelian, the oriental ruby, the garnet, and other precious stones. With different proportions of oxygen it imparts other and different colours.

are used in painting, enamelling, dyeing, and in medicine.

Where is tin *procured*[‡] *?*

Tin is found in Germany, in Saxony, and in the East Indies; but in England it is chiefly procured from Cornwall[§] and Devonshire.

What is the nature *of tin?*

Tin is a white metal, of little elasticity, and

Thus it gives the blue to the lapis lazuli, the yellow to the topaz, &c. See Additional Notes, No. 40.

[‡] Tin must have been known very early, as it is mentioned in the books of Moses. The edge-tools of the ancients, and their coins, were made with mixtures of copper and this metal.

Tin is found only in the primitive mountains. Its ores occur most frequently in granite, but never in limestone. About 3000 tons weight of tin are furnished annually in Cornwall. Sulphuret of tin and the brown oxide of tin are often found in the same county. See Additional Notes, No. 30.

[§] According to Aristotle, the tin mines of Cornwall were known and worked in his time. Diodorus Siculus, who wrote about forty years before Christ, gives an account of the method of working these mines: he says that their produce was conveyed to Gaul, and from thence to different parts of Italy. The miners of Cornwall were so celebrated for their knowledge of working metals, that about the middle of the seventeenth century the renowned Becher, a physician of Spire, and tutor of Stahl, came over to this country on purpose to visit them; and it is reported of him that, when he had seen them, he exclaimed, that "he who was a *teacher* at home, was a *learner* when he came there."

of but little taste. It is the lightest * of all the metals, and so exceedingly soft and ductile that it may be beaten out into leaves, thinner than paper.

What is the effect of oxygen *upon tin?*

Tin absorbs different proportions of oxygen, but as yet only two of its oxides have been much noticed, viz. the yellow † and the white; the first contains 20, the other 28 per cent. of oxygen.

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* The specific gravity of tin is 7.291, or about 516 pounds to the cubic foot: though the lightest of all metals except tellurium, it is much heavier than earths or stones.

The purity of tin may be known by its specific gravity; its purity being in exact ratio with its levity: while gold, on the contrary, is fine in proportion to its density.

Tin is much more combustible than many of the metals. It will burn in oxygen gas, before it acquires a heat sufficient to fuse it.

Tin is soluble in all the mineral acids. It may be precipitated from its solutions by potass; but an excess of potass will re-dissolve the metal. Nitro-muriate of gold is a test for the presence of tin in solution, forming a fine purple precipitate.

† A *yellow* oxide of tin may be procured by dissolving granulated tin in very dilute nitric acid, and precipitating it from the solution by an alkali: by pouring very strong nitric acid on granulated tin, a *white* oxide may be prepared, which precipitates in a pulverulent form, and is to be washed and dried for use.

The yellow oxide of tin found in commerce is called putty; but what is sold generally contains also oxide of lead. It is

What salts *of tin are there?*

The muriate, the nitro-muriate, and the sulphate of tin are most known; but many other salts may be formed with this metal. None of the salts of tin have been found native.

What are the uses *of tin?*

Tin is consumed in large quantities by the dyers[‡]; it is used also for covering sheet-iron to prevent its rusting[§], and in forming plumbers'

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employed in polishing fine steel goods, and the best kinds of ornamental glass.

A *white* oxide of tin is used to form the opake kind of glass, called enamel. This composition is made by calcining 100 parts of lead and 30 parts of tin in a furnace, and then fluxing these oxides with 100 parts of sand, and 20 of potash. But I am of opinion that soda would answer the purpose better than potash. To this enamel every kind of colour may be given by metallic oxides.

Tin by means of the muriatic acid decomposes water, and then, having been thus oxidized, readily dissolves in the acid to form muriate of tin. A solution of this metallic salt has a great affinity for oxygen. It deoxidizes a solution of indigo in an instant, and changes it from blue to green.

[‡] Tin is used to form boilers for dyers, worms for rectifiers' stills, and many other utensils employed in the arts.

[§] The consumption of tin for covering thin rolled iron, and forming what are improperly called sheets of tin, is very considerable: besides this, tin is used for coating the inside of iron and copper utensils, brass and iron pins, &c. For the method of doing this, consult Additional Notes, No. 30; or Gren's Principles of Chemistry.

The use of tin was known to the Grecians. Homer men-solder, speculum metal, pewter, and some other alloys. Its oxides are used in polishing glass, in glazing some kinds of earthen ware, and for various other purposes*.

What is the use of tin to the dyers?

Tin is employed by the dyers to give a brightness to cochineal, archil, and other articles used in forming reds and scarlets; and to precipitate the colouring matter of other dyes. For these

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tions it in the Iliad. Pliny says, the Romans learnt the method of tinning their culinary vessels from the Gauls. They used tin also to alloy copper for the purpose of making those elastic plates which they employed in shooting darts from their warlike machines.

Tin is employed to form bell-metal, bronze, brass for cannon, and a variety of other compounds. The addition of tin renders copper more fluid, and disposes it to assume all the impressions of the mould. With this view it was probably used by the ancient Romans in their coinage. Many of the imperial *large brass*, as they are called, are found to consist of copper and tin alone. Coins also frequently occur which are undoubtedly antique, that contain a very large proportion of tin, made by the forgers in the different reigns, in imitation of the silver currency. There are coins of Nero of a most debased and brittle brass.

* A combination of the white oxide of tin with sulphur by means of mercury, forms *aurum musivum* (mosaic gold), an article used by artists to give a beautiful colour to bronze. I suspect that the change produced in tin by this process gave rise to the idea of the transmutation of metals. If the alchemists were acquainted with this substance, no wonder that they should indulge the hope of being able to form gold. An experimentalist without theory is the dupe of every illusion.

purposes it is previously dissolved in a peculiar kind of aqua-fortis, called *dyer's spirit*†.

What is the nature of lead?

Lead is a heavy metal‡, of a pale, livid, white colour; slightly sonorous; has scarcely any taste; and emits a peculiar smell on friction. It has little elasticity, and yields readily to the hammer, being the softest of all metals. It generally contains a small portion of silver§, and sometimes mercury.

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† Several of the colouring substances which produced to the ancients only faint and fleeting colours, give us such as are brilliant and durable by the use of this metallic solution. A considerable degree of nicety and judgment is however requisite for its preparation; so much so, that there are many large dyers who can seldom prepare it so well as those who are fully acquainted with its chemical properties and effects, and make it an article of trade. The difficulty is in a great measure owing to the nature of the acid they use; as those makers of aqua-fortis who know nothing of chemical affinities, or of the nature and operation of this invaluable mordant, often furnish them with an article which is unfit for their use. Few arts have received such improvements from chemistry as the art of dyeing; for even cochineal gave but a dull kind of *crimson* till a chemist of the name of Kuster, about the middle of the seventeenth century, discovered the use of solution of tin, and the means of preparing with it and cochineal a durable and beautiful *scarlet*.

‡ The specific gravity of lead is 11.35.

§ Lead may be mixed with gold and silver in a moderate heat, but when the heat is much increased the lead rises to the surface combined with all heterogeneous matters. The

Where *is lead procured?*

Lead ore is found in great abundance in Scot-

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art of refining the precious metals is built upon this property of lead.

Lead, when dissolved in acids, has the property of imparting a saccharine taste to substances with which it may be mixed. The ancients knew that this metal rendered harsh wine milder, but did not suppose that it was poisonous. According to Pliny, the Greeks and Romans proved the quality of their wines by dipping a plate of lead in them. Beckmann's History of Inventions, vol. i. 398. 400. I have a treatise on the management of wines, printed so lately as 1783, which directs the use of lead in order to preserve them from acidity. How much is the present age indebted to chemical science, which instructs us respecting the properties of different substances! Some of our wine-merchants, probably in consequence of this direction, may have contaminated their wines with lead, without suspecting that they were distributing a slow poison to their customers. For the effects of lead on the animal system, consult a late work by Dr. Lambe, on the Nature of Spring Water. See Additional Notes, No. 31.

Lead will not only correct the acidity of wines, but it will also take off the rancidity of oils. With this intention, I have been informed, it is often used to make inferior olive oil pass for good.

Vats of lead have been used in some cyder countries, which have produced incalculable mischief.

"Lead, in its metallic state, like all the other metals, is probably inert: but it is so easily acted upon by the weakest acids and alkalies, that it cannot be taken even in this form without the most imminent danger." Johnstone on Poisons, 113.

Sir George Baker has carefully investigated the effects of lead on the animal œconomy, and in the 1st vol. of the Me-land, in Derbyshire, and in many other parts of the world *.

What is the effect of oxygen *upon lead ?*

Like other metals, lead presents us with a variety of its oxides †, and, according to the dose of

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dical Transactions, has fully described the *peculiar kind* of colic produced by it.

* Lead ore is generally found in veins, both in siliceous and calcareous rocks. Galena, or sulphuret of lead, is very common both in masses and crystallized. Lead is also found combined with silver, antimony, sulphur, and bismuth. Oxides of lead combined with various earths also occur in mining countries. Lead ochre is a native oxide of lead.

Lead was in common use among the ancients. The Romans sheathed the bottoms of their ships with this metal, fastened by nails made with bronze. During the first century, lead at Rome was twenty-four times as dear as it is now in Europe; whereas tin was only eight times its present price.

Lead, in the state of ceruse, was in great request among the Roman ladies as a cosmetic. Plautus introduces a waiting-woman refusing to give her mistress either ceruse or rouge, because forsooth, in the true spirit of a flattering Abigail, she thought her quite handsome enough without them. Bishop Watson.

The lead ores which are found in the primitive slate mountains contain much silver, generally 8 or 9 per cent.

† When lead is melted in an iron ladle, a scum will quickly appear upon its surface; if this be removed, another will immediately succeed, and in this manner the whole of the lead may be converted into a gray pellicle, which is the *gray* oxide of lead. If this gray oxide be exposed to a low red heat in a reverberatory furnace, it will acquire a further dose of oxygen,

oxygen, we have the gray, the white, the red, or the brown oxide * of this metal.

What salts *of lead are there?*

The salts of lead are very numerous, perhaps equal to the number of acids; but the muriate, sulphate, carbonate, and acetate of lead † are

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and be converted into yellow massicot; and if the heat be continued it will at length be changed to the *red* oxide of lead.

* If nitric acid of the specific gravity 1.260 be poured upon the *red* oxide of lead, 185 parts of the oxide are dissolved; but 15 parts remain in the state of a deep brown, or brilliant flea-brown powder. This is the *brown* oxide of lead, containing 21 per cent. of oxygen.

Lead may be converted into an oxide by heating it in a situation where it can have free access of atmospheric air. All the oxides of lead may be reduced to metallic lead by heating them with a mixture of tallow and charcoal, or any substance that will absorb the oxygen. This may readily be shown by placing a few grains of red lead upon a piece of charcoal, and fusing it with a blow-pipe. Even the oxide of lead which is combined with flint-glass may be revived by melting the glass with any carbonaceous substance.

Fourcroy says, that all the oxides of lead have the property of absorbing carbonic acid from the atmosphere; and that if an oxide of lead be required in a state of purity, it ought to be defended from the access of air.

† According to Mr. Hume, nitrate of lead, as a chemical test, should always be preferred to acetate of lead, as the last is so liable to give false results. Phil. Mag. vol. xx. page 160.

Lead forms an insoluble compound with sulphuric acid. Hence sulphuric acid is sometimes used to detect the presence of lead; but the best test is Harrowgate-water. To the susthose most known. The carbonate, murio-carbonate, sulphate, phosphate, molybdate, arseniate, and chromate of lead are native productions.

What are the uses of lead?

Lead is employed to cover buildings, to form water-pipes, to make a great variety of vessels for œconomical and chemical purposes ‡; and in refining gold and silver §. Its oxides are used for dyeing and calico-printing; in the manu-

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pected water add a little of this mineral water; and if lead be present it will give it a dark brown, or blackish tinge. For a method of detecting the presence of lead in wines, see Additional Notes, No. 31.

‡ Sheet lead is made by suffering the melted metal to run out of a box through a long horizontal slit in its bottom, while the box is drawn by appropriate ropes and pulleys along the table, leaving the melted lead behind it in the desired form to congeal.

An alloy of this metal with tin forms pewter, and in different proportions soft solder. It enters likewise into the composition of other useful alloys, especially one that is employed in the manufacture of white metal buttons; for it has lately been discovered that a certain proportion of lead may be mixed with the metal formerly used, without injuring the appearance of the button: thus affording a very considerable additional profit to the manufacturer. There is a considerable consumption of lead in making shot. See Additional Notes, No. 27.

§ Litharge of lead is often used in the analysis of the ores of what are called the *perfect* metals. It has the property of combining with all the other metallic oxides, and of preventing their evaporation during the cupellation; while it separates them from those metals which do not become oxidized by heat only.

factures of glass[*], earthen ware, and porcelain[†]; and in the preparation of various pigments.

What is the nature of nickel?

Nickel is a fine white metal, ductile and malleable, but of difficult fusion[‡]. It is attracted[§]

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[*] Lead is used in making the finer kind of glass, in order to give it a proper degree of weight, a susceptibility of its being cut without breaking, and a capacity to bear a higher polish.

[†] The oxides of lead and of tin were employed by the ancient Romans, in the manufacture of earthen ware, &c.

The oxides of lead dissolved in various menstrua, are used as embrocations, and for several other preparations, by the practitioners of medicine.

[‡] M. Richter has lately been occupied in a series of experiments upon nickel. He has found that this metal in its pure state is very malleable, nearly as brilliant as silver, and more attractable by the loadstone than iron. It is generally combined with copper; but he has found a method of freeing it from that metal. He says, that when pure it is not liable to be altered by the atmosphere; that it is perfectly ductile, and has great tenacity. Its specific gravity when forged is 8.666. Annales de Chimie, tom. liii. page 173.

[§] Many chemists have imagined that nickel and cobalt are magnetic only in consequence of a portion of iron which they contain; but in a paper in Nicholson's Journal, 8vo, vol. iii. 286, Mr. Chenevix has shown, that these metals are really magnetic; and that when they appear to be destitute of this property, arsenic is combined with them. Indeed, magnetic needles have lately been made with purified nickel, and have been esteemed more than those of steel, as being less liable to be affected by the air.

"So turns the needle to the pole it loves,
With quick librations trembling, as it moves."

by the magnet, and has itself the property of attracting iron ||.

Where, and in what state, is nickel found?

The ore of nickel is very similar to that of copper, and is procured from various parts of Germany; it is also often found with cobalt; but the nickel of commerce is always impure ¶.

What is the effect of oxygen *upon nickel?*

If purified nickel be exposed to atmospheric air* in an intense heat, it is slowly oxidized, and

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|| As common nickel always contains iron, the iron disguises its properties, and prevents its nature being exactly known. This metal dissolves readily in several of the acids, and communicates to them a green colour; but sulphuric acid acts very slowly upon it, even with the assistance of heat. Nitric acid dissolves it more readily.

¶ The most abundant ore of this metal is a sulphuret of nickel, called *kupfernickel*, which is generally a compound of nickel, arsenic, and sulphuret of iron.

It is a curious circumstance, that all the specimens that have been examined of the stones which have been said to fall from the atmosphere contain iron alloyed with nickel. These stones, which have at different periods been seen to fall on every quarter of the earth, are supposed by many to be cast from a volcano in the moon. So lately as 1803 a shower of them fell in Normandy, which covered an extent of three quarters of a league long, and half a league broad. Several dissertations on this curious subject may be seen in the latter volumes of the Philosophical Magazine; Nicholson's Journal; and other periodical and scientific works.

* An oxide of nickel is more easily obtained by exposure to heat with nitre; it is of an apple green colour. According to

then acquires an increase in weight of 33 per cent. We are acquainted with only one oxide of this metal *.

What salts *of nickel are there?*

Numerous salts have been formed with nickel, but none of them have hitherto been brought into any use. A native arseniate of this metal has been found †.

What are the uses *of nickel?*

Nickel is employed by the Chinese in making their *white* copper, which is a beautiful metallic compound; but it has not been much used in Europe, although it may be had in considerable quantities ‡.

Thenard, another oxide of this metal may be obtained of a black colour, by exposing the green oxide to a red heat, or by treating it with oxygenized muriatic acid. Phil. Mag. vol. xx. p. 67.

* Oxide of nickel is found in combination with some stones; the oxide may be dissolved in a solution of ammonia, and is not precipitated by sulphuretted hydrogen.

According to M. Richter, the oxides of *purified* nickel are of a much more lively green colour than the ordinary oxides; and their solution in ammonia is of a pale blue colour.

The oxide of nickel is said to afford the French manufacturers of porcelain a very delicate grass green; and, like other metallic colours, bears the intense heat of their ovens without injury.

A hyacinthine colour may be given to flint glass by melting it with this oxide.

† For a description of this native salt, consult vol. ii. of Kirwan's Mineralogy.

‡ It is generally said that nickel has never been brought into

What is the nature of zinc?

Zinc is a very combustible § metal, possessing but a small degree of malleability || and duc-

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use in England—but I have just heard from Birmingham, that some of the manufacturers of that town combine it with iron, and thus use it with great advantage; and that others melt it with brass in such proportions as form a very handsome compound metal, exceedingly useful for many purposes. The Chinese use nickel in conjunction with copper and zinc for making children's toys.

According to Proust, nickel, in a certain proportion, gives a degree of *whiteness* to iron, diminishes its disposition to rust, and adds to its ductility.

The valuable qualities, which M. Richter has discovered in this metal, show that it might be applied to many important uses, particularly for surgical instruments, compass-needles, and other such articles, as it is not liable to rust. Should an easy mode of working it be ever discovered, we may possibly find this to be better calculated for a variety of purposes than any other metal.

§ Zinc is so very combustible, that if beaten out into thin leaves it will take fire from the flame of a common taper. It is the most combustible metal we have. It has so strong an attraction for oxygen that it will decompose water without the assistance of heat. Excepting manganese, it has the strongest affinity for oxygen of all the metals. Its sp. gr. is 6.861.

|| Messrs. Hobson and Sylvester, of Sheffield, have discovered, that at a temperature between 210° and 300° of Fahrenheit, zinc is really a malleable metal; that it yields to the hammer, and, while kept at this temperature, may even be wire-drawn. They moreover say, that after having been thus annealed and wrought, it continues soft, flexible and extensible, and does not return to its partial brittleness, but may be bended

tility, except under certain circumstances *. When broken, it appears of a shining blueish white; and when exposed to the air, it becomes covered with a pellicle, which, in consequence of its affinity for oxygen and carbonic acid, reflects various colours.

How is zinc procured?

Zinc, generally called by our artists *spelter*, is not found native †; but, in England and else-

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and applied to many uses for which zinc has hitherto been thought unfit. If so, this is an important discovery; and in future there will be no impediment to its being formed into vessels of capacity, into utensils for various manufactories, sheathings for the bottoms of ships, and for other obvious applications.

Since the above was written, I have been informed that Mr. Phipson junior, an ingenious chemist of Birmingham, was acquainted with this property of zinc long before Messrs. Hobson and Sylvester took out their patent, and that he sent plates of this metal, which he had himself rendered malleable, several years ago to Dr. Priestley in America.

* The nature of zinc is such, that it seems to form the link between brittle and malleable metals. It is difficult to procure it in small particles, as the hammer flattens it instead of reducing it to powder. Macquer says, that if it be heated very hot, it becomes brittle, and may then be pulverized.

† Some mineralogists consider zinc to be the most abundant metal in nature, excepting iron. Calamine, or lapis calaminaris, is found both in masses and in a crystallized state, and is generally combined with a large portion of silex. Calamine is a *native oxide* of zinc, combined with carbonic acid. Zinc is

where, is extracted from calamine and other ores, by distillation ‡.

What is the effect of oxygen *upon zinc?*

Zinc is readily oxidized when it is heated; and at a white heat the absorption of oxygen, even in the common atmosphere, is so rapid and violent that the oxide appears to sublime; hence its oxide acquired the name of *flowers* of zinc. It may also be oxidized by acids. We are acquainted with only two oxides of this metal; viz., the yellow and the white oxide.

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found also in an ore called *blend.* In this state it is mineralized by sulphur. Workmen call it Black Jack—a mineral employed till lately in Wales for mending the roads.

In China there is a great abundance of zinc:—it is used in that country for current coin, and for that purpose is employed in the utmost purity. These coins have frequently Tartar characters on one side and Chinese characters on the other. They have generally a square hole in the centre, that they may be carried on strings and more readily counted.

‡ Metallic zinc is procured from calamine by distillation *per descensum.* The calamine is pounded, and with powdered charcoal put into large pots, which are placed in a furnace like a common oven. These pots have tubes fixed in their bottoms, which pass through the bottom of the furnace into a vessel of water. After the tops of the pots are covered, and rammed close with clay, a strong fire is made around them, so that the metallic zinc, being separated from the ore, and being of a volatile nature, is forced to rise to the upper entrance of the tubes, and thence passes downwards into the water.

In order to analyse the ores of zinc, it is necessary to operate upon them in retorts, and to collect the distilled metal in close

What salts *of zinc are there?*

A great number of salts[*] have been formed with this metal; but the carbonate, the sulphate, and lately the acetate of zinc[†] are most known; the two first are found in a native state.

What are the uses *of zinc?*

Zinc is combined with copper or tin, in various proportions, which constitute some of the most useful compound metals or alloys[‡]; it is also

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receivers; for, if reduced in a common furnace, the greater part of the produce would be dissipated. The same attention is necessary when operating upon arsenic.

Zinc may be known by dissolving it in a mineral acid, and then adding ammonia, which precipitates it of a white colour, and re-dissolves it instantly. Sulphuretted hydrogen added to a solution of this metal produces a white and lasting precipitate.

[*] Zinc has so great an affinity for oxygen, and its salts are so permanent, that none of the metals, except manganese, will precipitate it from its solutions in a metallic form.

[†] Sulphate of zinc, formerly called *white vitriol,* is usually formed in Germany from an ore called *blende,* which is a sulphuret of zinc. By the agency of fire and the access of atmospheric air, the sulphur is converted into sulphuric acid, and by means of proper evaporation and cooling the salt is obtained in a crystallized mass. The white vitriol of commerce ought never to be administered in medicine without previous purification; for, all I have examined contains copper as well as iron. Sulphate of zinc occurs in some mineral waters.

Acetate of zinc has been recommended by Mr. Henry to be applied in cases of inflammation. This salt is easily formed by dissolving flowers of zinc in acetic acid.

[‡] Three parts of copper, and one of calamine, or native carbonate of zinc, constitute *brass;* five or six of copper and one

used in medicine; it is the base of white vitriol; and its carbonate or oxide may be advantageously substituted for white lead in house-painting§.

What is the nature of antimony?

Antimony‖ is a brilliant, brittle metal; of a

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of zinc form *pinchbeck*. *Tombac* has still more copper, and is of a deeper red than pinchbeck. *Prince's-metal* is a similar compound, excepting that it contains more zinc than either of the former. A mixture of tin and copper with zinc forms *bronze*. Vessels of bronze, covered with silver, were dug out of Herculaneum. In order to make *brass*, the calamine is previously roasted; it is then mixed with charcoal and grain copper, and put into large crucibles, which are kept for a considerable time in a heat that will not melt the copper; after a time, the heat is raised so as to fuse it, and the compound metal is then run into ingots. Brass is a valuable alloy, on many accounts, especially in its not being so liable to tarnish by exposure to the air, as copper.

[§] See Annales de Chimie, No. 103.

Zinc, in fine filings, is used to mix with gunpowder, to produce those brilliant stars and spangles which are seen in the best artificial fire-works.

Zinc is generally one of the metals employed to form Galvanic batteries.

An amalgam of zinc is used to rub upon the cushions of electrical machines. It is very conveniently amalgamated, by melting it in a bowl of a tobacco-pipe, and pouring it while hot into the mercury. I have amalgamatized bismuth and other metals, but never found one of them to answer for electrical purposes equal to zinc, or an amalgam made with a mixture of tin and zinc.

[‖] According to Bergman, the specific gravity of antimony dusky white colour; and is destitute of ductility. Though seemingly hard, it may easily be cut with a knife*.

How is antimony procured?

Antimony is procured from an ore which is found chiefly in Hungary and Norway†.

What are the effects of oxygen *upon this metal?*

Antimony may be susceptible of several degrees

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is 6.86. If this metal be ground fine, and thrown into a dry glass jar filled with oxygenized muriatic acid, it will inflame immediately, and continue to burn with great rapidity and with a brilliant white flame. The combustion affords a beautiful spectacle. It also fulminates by percussion with oxygenized muriate of potash.

* Antimony may be known from bismuth thus:—Bismuth is very soluble in nitric acid, but antimony dissolves in it with difficulty.

† There are several ores of antimony, but the gray is the only one which is found in sufficient quantity for the manufacturer; it is a sulphuret of antimony. This ore is purified by exposure to a strong heat in a reverberatory furnace. By this process, the pure sulphuret runs from the earthy matter: this is afterwards remelted, and cast into cakes for sale. This sulphuret may be divested of nearly all its sulphur by long roasting, leaving the metal in the state of almost a pure oxide.

Native antimony, alloyed with a small portion of silver and iron, has been found in Sweden. I have been informed that it is found also in the state of Connecticut in America, nearly in the pure metallic form; that it frequently lies on the surface of the ground; that in some places entire hills of it are to be seen; and that Elihu White, esq. brought specimens of it to England for analysis.

of oxidizement; but at present we are acquainted with only two oxides of this metal; the one containing 18½, the other 23, per cent. of oxygen‡.

What salts of antimony are there?

Many different salts have been formed with the oxides of this metal; but those most known are the muriate of antimony §, the phosphate of lime and antimony ‖, and the tartrate of potass and antimony ¶. The first has been found native.

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‡ It was formerly supposed that antimony was capable of forming six different oxides; but Proust imagines that it is susceptible only of two definite degrees of oxidizement.

If oxide of antimony be precipitated by water from nitro-muriatic acid, the precipitate will be white; but if it be precipitated by a clear solution of galls, the precipitate takes a light yellow.

Some solutions of the oxides of this metal are very powerful and even poisonous when taken internally, except in very small quantities. See page 7.

§ Muriate of antimony is the common *butter of antimony* of the shops. The white oxide of antimony, called the *powder of Algaroth,* is made by merely dropping this solution into pure water. Muriate of antimony has been found native in Bohemia.

‖ The well-known medicine, called *James's powder,* is a phosphate of lime and antimony. It is a triple salt, in the form of a white powder. For a method of preparing it, consult Phil. Mag. vol. xi.

¶ *Emetic tartar* is a tartrate of potash and antimony, composed of about 56 parts tartrate of antimony, 36 tartrate of potass, and 8 of water.

What are the uses *of antimony?*

Antimony is combined with some other metals in making printers' types, and specula for telescopes. Its oxides are employed in medicine*, and in colouring glass. In times of remote antiquity it was used by females as a black pigment, for staining the eye-lashes.

What is the nature† *of* bismuth?

Bismuth is of a yellowish white colour, of a lamellated texture, and moderately hard, but not malleable. It is so brittle that it breaks readily under the hammer, and may be reduced even to powder‡.

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* Perhaps we have no metal more valuable as a medicine than antimony, or one that is applied in such various ways. For particulars, consult the New Edinburgh Dispensatory, by Dr. Duncan jun.

Kermes mineral, and what was called *golden sulphur* of antimony, are both made from the sulphuret of this metal, by means of potass. The first took its name from its resemblance in colour to the kermes insect, used in dyeing. The sulphuret, and some other preparations of antimony, are given to horses and cattle, more than any other medicines. They act as alteratives, and are generally to be depended upon for the certainty of their effects.

† If water be added to a solution of bismuth in nitric acid, the oxide will be precipitated of a pure *white* colour; but if a little tincture of galls be poured into a similar solution, a *brown* precipitate will be produced. This is the distinctive characteristic of this metal.

‡ Bismuth has the singular property of *expanding* as it cools,

How is bismuth procured?

Bismuth is generally found with cobalt in the cobaltic ores of Saxony and England. Native bismuth and sulphuret of bismuth are also found upon the continent; but this is not an abundant metal.

What is the effect of oxygen *upon bismuth?*

Bismuth is gradually oxidized by fusion in atmospheric air; and may be thus converted into at least two varieties of oxides§.

Hence, probably, its use in the metallic composition for printers' types; as from this expansive property are obtained the most perfect impressions of the moulds in which the letters are cast. In manufactories this metal is known to the workmen by the name of *tin-glass*. Its sp. gr. is 9.8227. The larger kind of printers' types, are generally made with lead and antimony only; in the proportion of 4 parts of the former, to one of the latter. It surely is not possible to contemplate the advantages that the world has derived from the invention of printing, without very peculiar emotions!

"Sad Superstition wails her empire torn,
Art plies his oar, and Commerce pours her horn."

Bismuth is one of the metals that will inflame when thrown into oxygenized muriatic acid.

§ *Pearl-white* is an oxide, or rather a sub-salt, of this metal. Ladies use it for painting the skin, to which it imparts a beautiful white: but it has the inconvenience of becoming black by the contact of sulphuretted hydrogen gas, or the fumes of fetid substances. The gas which arises from the burning of mineral coal will have the same effect. It is related of a lady of fashion, who had incautiously seated herself too near the fire at a quadrille-table, that her countenance changed on a sudden from a

What salts *are there of bismuth?*

Several salts of bismuth have been formed, but their properties have not been much examined by chemists. The nitrate* and muriate of bismuth† are occasionally prepared, but no salts of this metal have been found in a native state.

What are the uses *of bismuth?*

Bismuth is used with other metals to form printers' types, to make pewter‡, and for some

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delicate white to a dark tawny, as though by magic. The surprise and confusion of the whole party had such an effect upon the disfigured fair-one, that she was actually dying with apprehension, when the physician dispelled their fears, by informing his patient that nothing more was necessary than for her to wash her face, to abstain from the use of mineral cosmetics, and to trust in future to those charms which nature had bestowed upon her.

Some of the French chemists recommend the use of the oxides of bismuth for dyeing, to fix some particular colours. Pomatum prepared with the oxide of bismuth turns the hair black.

* Nitrate of bismuth does not dissolve in water like other metallic salts, but becomes decomposed, forming one of the most delicate white precipitates: hence, this metal is readily distinguished from most others. This precipitate, washed and dried, is what has been called *Magistery* of bismuth, or pearl white.

† *Butter* of bismuth, as it was formerly called, is a muriate of this metal.

‡ The common mixture for *pewter* is 112 pounds of tin, 15 pounds of lead, and 6 pounds of brass; but many manufacturers use also bismuth and antimony to compose metal. Bismuth is likewise generally mixed with tin for vessels of

other compounds. It remarkably contributes to the fusibility§ of some alloys; hence, it is employed to make solder. Bismuth is likewise given in medicine, though, now, very rarely.

What is the nature|| *of arsenic?*

Arsenic is generally found in combination with acids¶, sulphur, or oxygen*. When reduced to its pure metallic state, it is a friable, brilliant metal, of a blueish white colour, easily tarnish-

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capacity, &c., as it gives to that metal a greater degree of brilliancy and hardness. From its property of rendering lead more fusible, it is too often employed with that metal to adulterate quicksilver.

§ If 8 parts of bismuth, 5 of lead, and 3 of tin be melted together, the mixed metal will fuse at a heat no greater than 212°. Tea-spoons made with this alloy are sold in London, to surprise those who are unacquainted with their nature. They have the appearance of common tea-spoons, but melt as soon as they are put into hot tea. A composition of lead, zinc, and bismuth in equal parts, will melt with so small a portion of caloric, that it may be kept in fusion upon *paper* over a lamp.

|| Arsenic may be known by the smell of garlic, and by the white fumes which it exhales when thrown on a piece of red hot coal. Its sp. gr. is 8.310.

¶ Nitrate of arsenic will precipitate the salts of copper of a beautiful green colour. This precipitate is exactly the same as the native arseniate of copper found in the mines of Cornwall.

* The oxides of arsenic in solution are discovered by sulphuretted hydrogen, which produces a yellow-coloured precipitate. This precipitate is the same as that beautiful ore called orpiment (sulphuret of arsenic).

ing, that is, oxidizing, by exposure to the air*. In all its states it is poisonous†.

Where is arsenic found?

Arsenic is found in Bohemia, Hungary, Saxony, and other places on the continent‡. It is

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[*] If arsenic, in its pure metallic state, be kept covered with alcohol, its metallic brilliancy will be preserved.

If metallic arsenic be previously inflamed in oxygen gas, it will burn till the whole is consumed. It burns with great brilliancy, and forms a very beautiful experiment.

[†] Dr. Pearson has said, that white arsenic, in the quantity of one-sixteenth part of a grain, is as harmless as a glass of wine, and, in that dose, is a remedy for inveterate agues. See Dr. Pearson on Sulphate of Iron, &c. Phil. Mag. vol. xxi. 56.

Whenever arsenic has been taken internally, by design or mistake, the best medicine is sulphuret of potash (liver of sulphur) dissolved in water. A few scruples should be dissolved in half a pint or a pint of water, and administered a little at a time as the patient can bear it.

[‡] The arsenic of commerce is prepared in Saxony in the operation of roasting the cobalt ores for the manufacture of zaffre. The reverberatory furnace in which the ores are roasted terminates in a long horizontal chimney; and in this chimney the arsenical vapours are condensed, forming a crust, which at stated times is cleared off by criminals, who are condemned to this work for crimes for which they would otherwise have suffered death. White arsenic is prepared by mixing the common oxide with potash, and submitting it to sublimation. By this process the arsenic is separated, and sublimed, leaving its sulphur behind, united to the potash.

In analysing the ores of arsenic, or the ores of any of the metals whose oxides are volatile, the upper part of the crucible should always be filled with charcoal; so that whatever is united with, and contaminates, many of our metallic ores in England[§].

What is the effect of oxygen *upon arsenic?*

Arsenic has a great affinity for oxygen, of which it admits of various doses, till it becomes at last arsenic acid[‖].

What salts *of arsenic are there?*

The salts which have been formed with this metal are few: though muriate of arsenic was made by the old chemists; it was called *butter* of arsenic. None of the salts of this metal are found native[¶].

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volatilized may be caught by the charcoal, and immediately reduced.

[§] Arsenic is frequently found in martial pyrites, and in copper ores. See Gellert's Metallurgic Chemistry, and Henkel's Pyritologia.

Lead, when contaminated by arsenic, may be purified by melting it with a few iron filings. The iron combines with the arsenic, and these, being lighter than the lead, float on the surface, from which it may be readily skimmed off.

[‖] Arsenic is capable of combining with so large a portion of oxygen as to become changed into a perfect acid. See page 234. There are four other metals which are completely acidifiable; viz. chromium, molybdenum, tungsten, and columbium: there is, however, some doubt respecting the acidifiable nature of tungsten.

[¶] Though there are no native salts in which arsenic forms the base, yet we are acquainted with several in which it is combined as an acid; such are, the arseniates of lime, copper, iron, cobalt, &c.

What are the uses of arsenic?

Arsenic, in a reguline state, is used to whiten copper*, and it enters into the composition of several compounds for metallic specula, &c.† Its oxides are employed in many processes of the dyer‡; also as fluxes for glass, and in several of the arts. The sulphurets of arsenic form valuable pigments of different colours§.

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[*] Copper alloyed with arsenic, forms a malleable and flexible metal that takes a fine polish. On account of these properties, this mixed metal is frequently used in the arts, plated with silver.

[†] The use of arsenic, in making factitious metals for the specula of reflecting telescopes, may be seen in a long paper on that subject by the Rev. John Edwards of Ludlow, in the Nautical Almanac for 1787.

Arsenic is used in making small shot. The design of it is to render the lead more brittle, and better capable of granulating. See Additional Notes, No. 27. It is employed also in the manufacture of glass, to which it gives transparency.

It is curious that if arsenic be combined with the ductile metals, it renders them brittle; but if with platina and some other metals that are refractory in the fire, it makes such more fusible.

[‡] Arsenic, when used in dyeing, is generally combined with potass. Baumé has long made a trade of preparing this salt for the French dyers.

[§] Sulphuret of arsenic is much used in calico-printing, on account of its property of readily dissolving indigo.

Orpiment and realgar are both sulphurets of arsenic. Realgar is a dark orange or scarlet, the other a beautiful lemon colour. They are both much used in dyeing and calico-printing.

What is the nature *of cobalt?*

Cobalt is a whitish-gray, brittle metal, nearly resembling fine hardened steel‖. It is difficult of fusion and oxidizement, but obedient to the magnet.

The former has lately been found native in Cornwall. The pigment called *king's* yellow is made from this mineral. Beautiful shades of different colours may be given to valuable furs by arsenical solutions.—So that the substance which is most injurious to the animal œconomy, appears to be endowed with properties for embellishing the works of creation, and is made to minister in various ways to our gratification, by imparting colour to other bodies. How diversified are the means which the Creator hath adopted for the promotion of these designs!

"Who, not content
With every food of life to nourish man,
By kind illusions of the wondering sense,
Has made all nature beauty to his eye,
Or music to his ear." AKENSIDE.

Arsenic is used in preparing the beautiful colour called *Scheele's green.* For the method of making this colour, consult Scheele's Chemical Essays, Gren's Chemistry, and others.

Sulphuret of arsenic has lately been employed with success in destroying the intolerable fetor which sometimes attends cancerous complaints. The method of using it is by fumigation.

The Chinese and other Orientals form *realgar,* sulphuret of arsenic, into medical cups, and use lemon juice that has stood some hours in them, by way of cathartic.

‖ According to Bergman, the specific gravity of cobalt is about 7.700; though Tassaert makes it to be 8.538.

Solutions of cobalt give a *green* colour by evaporation and heat. This may be shown, by moistening a little paper with

How is cobalt procured?

Formerly all our cobalt came from Saxony[*]; but it is now found abundantly in the Mendip hills in Somersetshire, and in a mine near Penzance, in Cornwall[†].

What is the effect of oxygen *on this metal?*

Cobalt may be oxidized by an intense heat. The oxygen prepares it for that beautiful blue

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the solution, or writing with it on paper, and drying the paper by a gentle heat. The oxide of cobalt in ammonia forms a red solution.

[*] The cobalt ores of Hesse now produce a net profit of 14,000*l.* a year: formerly they were used for no other purpose but to repair the roads. Born's Travels.

[†] Zaffre is now made from the cobalt ores found in these hills. Had it not been for the rapid promulgation of chemical science in these kingdoms, this important metal might have lain in the bowels of the earth undiscovered, for ages yet to come.

> "Full many a gem of purest ray serene
> The dark unfathomed caves of ocean bear;
> Full many a flower is born to blush unseen,
> And waste its sweetness on the desert air." GRAY.

Cobalt ores generally contain arsenic; they are so contaminated with it, that the workmen who are employed seldom live many years. It is to be hoped that some mode will be devised to protect these wretches from the baneful effects of this mineral.

Cobalt ores may be analysed thus: Take 100 grains of the ore, dissolve them in nitrous acid, precipitate the iron by the addition of ammonia, and separate it from the solution by a filter. The nickel, which is always found in these ores, may afterwards be precipitated by the addition of a solution of potass, colour which is seen on earthen-ware and porcelain[‡]. There are at least three different oxides of cobalt[§], which are known to chemists.

What salts *are there of cobalt?*

A great variety of salts have been formed with the oxides of this metal; but the muriate of cobalt is that which has, perhaps, been longest known[‖]. An arseniate and a sulphate of cobalt have been found native.

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and separated in the same manner as the iron. The remaining solution may be evaporated to dryness, and the oxide reduced by the usual fluxes.

The white cobalt ore is a sulphuret of cobalt. Arseniate and sulphate of cobalt have also been found native.

Cobalt, for experiment, might easily be obtained in a metallic state, by fusing *strewing-smalt* with 6 or 8 times its weight of soda. The soda forms an union with the sand, and leaves the cobalt free.

[‡] The oxide of cobalt forms the most permanent blue colour that we are acquainted with. La Grange says that the old painters used this oxide mixed with oil in their paintings; which is the reason why the sky and drapery in some old pictures are of so durable a blue.

[§] Zaffre, which we have long imported from Saxony, is an oxide of cobalt, mixed with three times its weight of ground silex. There are the black, the brown, and the yellow cobalt ores, all which are oxides of this metal.

[‖] Muriate of cobalt much diluted has been long used in forming Hellot's sympathetic ink. Whatever is written on paper with this ink remains invisible, while it is cold; but if the paper be gently warmed, the letters will appear of a beautiful green colour:—thus, by warming or cooling the paper, the writing may be made to appear and disappear at pleasure.

What is the use of cobalt?

Cobalt has hitherto been chiefly used for making the different kinds of smalts for painting and enamelling*. It is extremely valuable to the manufacturers of porcelain, as it endures the intense heat of their furnaces without any deterioration, and produces a finer colour than can be procured from any other known substance†.

It is, however, from some iron generally found in cobalt that the muriate forms a *green* ink; for, if it be perfectly pure, it is always of a most beautiful blue; so that by proper management one may be provided with both. By means of these two inks, a picture of winter may be drawn, which, on holding it near the fire, will be transformed to a beautiful summer landscape: this again will appear gradually to lose its verdure, and resume its winter dress, on being removed to a cold situation. The *acetate* of cobalt is always of a *red* colour in solution, but as a sympathetic ink it is a fine *blue*.

* The *strewing-smalt*, an article used by sign-painters, is made by melting the oxide of cobalt with flint-glass, and grinding the whole to a coarse powder. The same composition reduced to an impalpable powder forms the smalts for washing, sold under the name of powder blue; which is now not only used by laundresses, but is made the basis of several pigments.

In the fifteenth century cobalt was employed to colour glass, and yet till lately but small quantities of it have been used. Formerly the miners threw it aside as useless. They considered it so troublesome when they found it among other ores, that a prayer was used in the German church that God would preserve miners from *cobalt*, and from *spirits*. Beckmann's History of Inventions, vol. ii. 363. Other ancient uses of this metal, as a colour, may be seen in the same work.

† The greatest consumption of cobalt is by the potters and

What is the nature of manganese?

Manganese is a brilliant metal[‡], of a dark gray colour, of considerable hardness, and difficult fusibility. It is very brittle, and when in powder is attracted by the magnet.

Where is manganese found?

The manganese, which we use in this country, is obtained in the state of black oxide, from the Mendip hills in Somersetshire, and at Upton-Pyne, three miles from Exeter[§]. It is also found

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porcelain manufacturers, some of whom make their own colour from foreign zaffre. But in Staffordshire there are several people who make an entire trade of preparing this colour for the earthen-ware manufacturers, and who conduct the process with great secrecy. The usual price of the prepared colour is two guineas the pound.

[‡] The specific gravity of manganese has been estimated at 6 850 by Bergman.

For a method of procuring this metal in a metallic state, see Dr. Thomson, vol. i. 242.

The oxides of manganese are abundant, and easily procured; but the *pure* metal can only be obtained by art, and requires to be carefully defended from oxygen, which it readily absorbs.

In order to preserve specimens in a metallic state, it is necessary to varnish them, or to keep them immersed in oil, or ardent spirits.

Where manganese is employed in making oxygenized muriatic acid for medicine, the purest, such as that of Upton-Pyne, should be used. That from Bristol and the Mendip hills generally contains lead. Thornton's Medical Extracts, vol. v. 403.

[§] Manganese is generally found either in the state of an oxide or a salt. But the discovery of English mines of it is a in abundance in America, and on various parts of the continent. Pure manganese is never found native.

What is the effect of oxygen *upon manganese?*

This metal will become oxidized by mere exposure to the air; and is susceptible of at least three different degrees of oxidizement, forming white, red, black, or other oxide of manganese*.

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new acquisition to this country, owing to the spirit of research which chemistry has given birth to.

Dr. William Dyce, of Aberdeen, has lately communicated to the Society for the Promotion of Arts, &c., the discovery of a mine of manganese in his vicinity, of great extent, and of very fine quality. The gold medal of the Society was awarded to him for this discovery. The present produce of the mine is 20 tons per week.

Oxide of manganese is frequently found in stones and minerals. When the mineral is dissolved, it may be precipitated from its solution by ammonia.

Scheele discovered this metal in the ashes of burnt vegetables.

Proust has lately announced the discovery of a *native sulphuret* of manganese.

* The methods of giving the different degrees of oxidizement to this metal, may be seen in Dr. Thomson's Chemistry, vol. i. 243.

If one part of the black oxide of manganese, and three parts of nitrate of potass, be melted in a crucible till no more oxygen gas is disengaged, a greenish friable powder is obtained, called *mineral cameleon*, from its property of changing colour when dissolved in water. If a small quantity of this powder be put into a glass of water, the solution is first *blue*; oxide of iron then separates, and by its *yellow* colour renders the solution

What salts *are there of manganese?*

A variety of salts have been made with the oxides of this metal; but this class of salts has not yet been rendered useful†. A carbonate of manganese is found native in Norway and Sweden.

What are the uses *of manganese?*

The oxides of manganese are used in bleaching‡, in purifying glass§, and in glazing black

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green; this subsiding, the blue re-appears: then, as the oxide of manganese absorbs oxygen from the atmosphere, it becomes reddish, brownish, and at last black. It then subsides, and leaves the fluid colourless. Parkinson. In forming this compound, care should be taken that no sulphur comes in contact with it; as the addition of a very small portion of sulphuret of potass would counteract its effects.

The *rubelite* and the *amethyst* owe their colours to the *red* oxide of manganese. A *violet* colour may be given to flint glass by melting it with a large portion of the *black* oxide of this metal

† There is a peculiarity attending the salts of manganese, that, when dissolved in water, the manganese cannot be precipitated from its solution, in a metallic state, by any of the other metals. The reason is, that, in respect to all other metals, manganese has a superior attraction for oxygen.

‡ Manganese is used by the bleachers in making the oxygenized muriatic acid, which has the property of destroying all colours.

§ Its use in making white flint glass may be seen in Berthollet's Treatise on Dyeing, vol. i. 8. It was employed for this purpose more than two thousand years ago. The rationale of its operation has been admirably explained by Bergman. See Murray's Chemistry, vol. iii. p. 435.

Dr. Dyce has suggested, that manganese may be advantage-earthen-ware. The black oxide is also much used by chemists for procuring oxygen gas, which it gives out in abundance, by the application of a red heat*.

What is the nature of tungsten?

Tungsten is a heavy metal, procured from a mineral found in Sweden, and from an ore called *wolfram*, found in our county of Cornwall, in Germany, &c.; but its properties are not much known, neither is it brought into any use here†.

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ously employed to separate the pure from the baser metals. An account of the process may be seen in one of the last volumes of the Transactions of the Society of Arts, &c.

According to monsieur Gazeran, manganese forms a component part of steel, and ought to be added to iron for its formation; the best German steel being, according to him, composed of

Iron	97
Manganese	2
Carbon	1
	100

* Black oxide of manganese contains 40 per cent. of oxygen. It quickly gives out 10 or 12 per cent. of this oxygen by the application of heat alone, but the remaining portions cannot be separated by the most intense heat.

† Tungsten has been used in France for making vegetable lakes. Its sp. gr. is 17.22. Its oxide is insoluble in either of the three mineral acids; and in this property it seems to differ from all other metals. Though tungsten has been recommended as a proper basis for colours, it shows in some instances a strange fugacious disposition. Mr. Hume left a piece of zinc

The same may be said of molybdenum[‡], uranium[§], titanium[||], tellurium[¶], chromium[*], columbium[†], and tantalium[‡]. It will therefore be proper to defer the consideration of these metals till their properties have been further investigated.

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for some time in a little of the triple acidulous solution of this metal, generally called tungstic acid, and obtained a most brilliant blue solution: this he placed over the gentle heat of a lamp to evaporate, with a view to obtain a useful pigment; it soon, however, entirely lost its colour. Phil. Mag. vol. xix. 29.

[‡] Molybdenum has been employed, I believe, in some processes of dyeing in Germany. As it may be procured in great plenty, it will probably some time hence come into general use here.

[§] Uranium was discovered by Klaproth in a mineral called pechblend; it has since been found, combined with carbonic acid, in the common green *mica*.

[||] Titanium was first noticed by Mr. Macgregor, in a grayish black sand, found in the vale of Menachan in Cornwall; but it has since been discovered by Klaproth in several other minerals.

[¶] Tellurium was discovered by Klaproth in a particular kind of gold ore.

[*] A beautiful green colour may be obtained from chromium, useful for painting in oil or *distemper*, or for applying to porcelain. The metal was called chromium, because of its property of imparting lively *colour* to a variety of other bodies.

[†] Columbium was discovered in a mineral sent from Massachusetts, in North America. See Mr. Hatchett's paper on this metal in the Philosophical Transactions for 1802.

[‡] Tantalium was found in an ore from Swedish Lapland. Its characteristic is, that it is insoluble in all the acids.

Having gone through the greater part of this chapter on metals, endeavour to recapitulate the general properties of this class of bodies.

The metals are simple substances*, distinguishable from all other bodies by their lustre, by their great specific gravity, by their perfect opacity, and by their superior power of conducting electricity.

What are the obvious advantages which we derive from these bodies?

The metals are the great agents by which we are enabled to explore the bowels of the earth, and to examine the recesses of Nature; their uses are so multiplied, that they are become of the greatest importance in every occupation of life. They are the instruments of all our improvements, of civilization itself, and are even subservient in the progress of the human mind towards perfection†.

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* The ancient chemists supposed the metals were *compound* bodies. They were probably led to this by observing the pulverulent nature of the metallic oxides. Their undecompounded nature was first suspected by Mayo.

† The metals are seldom afforded by Nature otherwise than in a state of great impurity. It is to the use of our reasoning faculty that we owe the possession of any of them in a state fit for use. If we consider for a moment what would be the situation of the world if society were deprived of this class of bodies, we should then have some idea of the obligations we owe to the sciences of metallurgy and chemistry.

You can doubtless offer some reasons why one metal possesses such opposite and specific differences from another‡ ?

This variety is not to be attributed to chance, but must certainly be the effect of consummate wisdom and contrivance§. These metals differ so much from each other in their degrees of hardness, lustre, colour, elasticity, fusibility, weight, malleability, ductility, and tenacity, that Nature seems to have had in view all the necessities of man; in order that she might suit every possible purpose his ingenuity can invent, or his wants require,

By what means are these bodies rendered so important to us?

We not only receive this great variety from

———— " Serene philosophy,
Effusive source of evidence and truth!
Without thee, what were unenlighten'd man?
A savage roaming through the woods and wilds,
Rough clad, devoid of every finer art
And elegance of life." THOMSON.

The best information respecting the analysis of metallic ores may be had from Klaproth's Essays, to which I refer the reader.

‡ Much information on the nature of many of the metals may be collected from Mr. Hatchett's valuable paper on gold, in the Philosophical Transactions for 1803.

§ " That beautiful law of Nature, whereby the different unorganized productions are impressed with regular forms, doth not cease to exist even under the hands of man in his various the hand of Nature, but these metals are rendered infinitely valuable by various other properties they possess. By their combustibility*, their solubility in fluids, their combinations with phosphorus, sulphur†, and carbon, and by their

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experiments. He finds the metallic ores, under determinate forms, or geometrical figures of different kinds; and, when by art he reduces them to a metallic state, the same disposition still manifests itself." Thus, when the surface of a melted metal begins to congeal, if the crust be broken and the part still in a fluid state drawn off, the parts which had cooled will exhibit a regular metallic crystallization. It would afford a rational amusement, to make experiments thus on the different metals, and to observe the forms of crystallization which they each assume.

* Some of the metals are so combustible that they will burn before they acquire a heat sufficient to fuse them. This is the case with iron and zinc. A thin shaving of zinc, as we before noticed, will burn without melting if held in the flame of a candle. The combustion of iron in oxygen gas is an interesting and beautiful experiment. See an account of the method of managing it in the chapter on Combustion.

A very singular phænomenon takes place on the mixture of the metals with melted sulphur; for, as soon as the union commences, the temperature increases, and a considerable glow of light is extricated, similar to what happens in combustion. The same effects take place in hydrogen gas, and carbonic acid gas, and even in vacuo. These experiments have been adduced as objections to the modern theory of chemistry; but they merely tend to show that, in common cases of combustion, the *light* comes in part from the combustible, and not the whole of it, as has been imagined, from the atmospheric air. Light and heat attend other combinations, as well as those of oxygen.

† All the metals except platina and gold will unite with

union with each other [‡]; whereby compounds or alloys are formed, extremely useful in a variety of arts, manufactures, and other requisites of life.

By what other means does Nature render these bodies subservient to our wants, and capable of ministering to our comfort and gratification?

Nature has furnished us with acids, whereby the most refractory metals may be dissolved [§], purified, and rendered fit for a variety of purposes, to which they could not otherwise be

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sulphur by fusion. But the natural sulphurets contain more sulphur than the artificial ones; they must therefore have been formed by Nature by other means than those we employ to produce these compounds.

[‡] Several of the metals have a very strong affinity for each other, as may be shown by experiment. Mercury will dissolve lead, bismuth, zinc, and other metals. If a piece of lead and a piece of bismuth each alloyed with mercury, be melted together, they form when cold a solid metallic mass; but from their affinity for mercury they have acquired so much fusibility that they will melt by the heat of boiling water. See note, page 413.

[§] The alchemists were in search of an universal *solvent* of all metals; but, as Mr. Davy has remarked, if such a solvent really existed, nothing would be so much dreaded by modern chemists. It would prevent the analysis of every mineral into which it entered, and would be like the fabled water of the Styx, which petrified every thing it touched. How different are the views of the scientific chemist to those of the ancient adepts, who concealed their knowledge with the greatest care, and appear to have had no other view but to surprise a gaping multitude!

applied. By combining the metals with oxygen[*] we can invest them with *new* properties, and are enabled to employ these to promote the progress of the fine arts, by imitating the masterpieces of creation, in the production of artificial salts, spars, and gems, of every colour, and of every shade[†].

How does oxygen produce these changes in metals?

Different metals, by their union with oxygen, acquire different colours, and the same metal attains a different hue, according to the portion of oxygen combined with it[‡]; so that this wonderful substance seems destined not only to render us the most important services, but to embellish the works of creation, by the beautiful tints which

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[*] This is exemplified in a striking manner by the metal called chrome. When acidified and combined with lead, the metallic salt that results is of a beautiful orange yellow; whereas chromat of mercury is of the colour of vermilion; chromat of silver, of a carmine red; chromat of zinc and bismuth, a bright yellow.

[†] If phosphoric acid be united with silex by fusion, artificial precious stones may be prepared with the compound, which may be coloured to imitate any particular kind, by one or other of the metallic oxides.

In making enamels and artificial gems, the processes of Kunkel may be depended upon more than those of any other writer. He was the superintendant of several foreign glass-houses.

[‡] The oxide of iron is an eminent example of this change of

it imparts to almost all subjects, whether of the animal, vegetable, or mineral kingdom §.

You seem to think that the changes which metals undergo by their absorption of oxygen are the most surprising phænomena of nature:—can you recollect some other properties of oxygen, to serve as a comparison, and to elucidate its importance?

When I consider, in addition to the multiform effects of oxygen upon metals ||; that no animal can exist, no acid can be formed, no kind of combustion whatever can take place, nor even the most insignificant vegetable perform its proper functions, without the agency of this most astonishing substance; I cannot but exclaim—We want no further proofs to demonstrate, that the organization of the world has been effected

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colour. No less than seven distinct colours, besides a great variety of shades, are observed in minerals containing iron; and to the iron in most cases is the colour to be ascribed. See p. 12.—White in the somnite. Black in the obsidian. Green in the euclase. Blue in the lazulite. Red in the garnet and ruby. Yellow in the topaz. Brown in the tourmalin.

§ I would recommend to the preceptor the perusal of an interesting paper on oxygen, by Fourcroy, in one of the volumes of the Annales de Chimie. I apprehend that a more comprehensive idea of the nature and operation of this wonderful substance may be acquired by reading that essay, than from most other treatises on that subject.

|| It is no unusual thing for chemistry to be called by its votaries a fascinating science. That it is the most useful of all sciences cannot be denied; nor can there be the least doubt

by consummate wisdom and goodness—attributes belonging to HIM only, who has thus supplied our wants, and ministered to our comforts, and even to our luxuries. Other instances might be enumerated in which oxygen is indispensably necessary. Its importance is, however, too eminently conspicuous to be overlooked in the formation of WATER; *three-fourths* of every particle of which, whether we consider it in the ocean, or in the lakes, rivers, and fountains, that pervade every corner of this material world; or contemplate the immense quantity always floating as vapours in its atmosphere; we shall find to consist of this one important *simple* substance, OXYGEN.

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that it has a strong tendency to enchant those who devote their attention to it. It serves as a powerful stimulus to youth, as it occupies their time so satisfactorily to themselves, and renders all low and unworthy pursuits truly detestable. But amidst the great variety of subjects, which this science embraces, the changes which the metals undergo, by their absorption of oxygen, are perhaps more eminently calculated than any other of its departments, to give a relish for chemical pursuits, and to engage the young mind in the unremitted examination of the works of creation.

"The philosophic youth
To NATURE's voice attends, from month to month,
And day to day, through the revolving year;
Admiring, sees her in her *every* shape;
Feels all her sweet emotions at his heart;
While TRUTH, divinely breaking on his mind,
Elates his being, and unfolds his powers." THOMSON.

CHAP. XI.

OF OXIDES.

What is an oxide?

Any one or more of the simple substances, when united to a less quantity of oxygen than is necessary to form an *acid*, is called an *oxide*.

What substances are capable of forming oxides?

The mineral, the animal, and the vegetable kingdoms, all furnish matters which are convertible into oxides by a union with oxygen[*].

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[*] The oxides appear to range themselves into two classes. There are oxides which are permanently such, so long as they retain the oxygen which enters into their formation; and there are others which seem to possess only a kind of intermediate state between combustibles and acids, being convertible into acids by a further portion of oxygen. This will appear as we proceed.

According to the old theory, metals were supposed to be oxidized by the loss of phlogiston; and when these oxides were reduced to a metallic state, it was imagined that they recovered their phlogiston from the carbonaceous matter employed in their reduction. Those persons who have not been in the habit of reading the works of the older chemists may understand

In what way do metals become united to oxygen?

There are several ways in which metallic oxides are formed, the chief of which are by the access of atmospheric air, by the decomposition of water, and by the decomposition of acids.

Will all metals become oxidized by exposure to the air?

No: gold, silver, and platina, cannot be oxidized, unless in a very high temperature; though iron*, copper, and lead, by long exposure to the air, will become oxidized in the coldest atmosphere. Manganese, by such exposure, will in a few hours be converted into a perfect oxide.

Are metals ever exposed to the air with the design of converting them into oxides?

The common red lead of the shops, which is a true oxide of lead, is made by melting that me-

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them by attending to the following particulars: In most cases, all that is necessary is to substitute the word *oxygen* for *phlogiston,* with a slight inversion of the language. For the effects which they attributed to the combination of phlogiston appear to be due to the extrication of oxygen; and what they supposed to be owing to the loss of phlogiston was really occasioned by the absorption of oxygen.

* Metals not only become oxidized by atmospheric air, but sometimes, by exposure to its action, pass from a lower to a higher degree of oxidizement. Thus, if a solution of the common sulphate of iron be exposed to the atmosphere, it acquires a further dose of oxygen, and by degrees a portion of the metal is precipitated.

tal in ovens, so constructed as to have a free access of atmospheric air[†].

How is it known that the change of common lead to red lead is caused by the absorption of oxygen?

This is known by the increase of weight which the metal acquires during the operation[‡]; and to confirm the fact, the oxide may be again reduced, and the original quantity of metal left unaltered.

Do all metals increase equally when converted into oxides?

No: each metal has its extremes, between

[†] Some of the metallic solutions cannot be formed but in contact with oxygen or atmospheric air. Thus, copper or lead, placed in acetic acid, and excluded from the air, does not form any solution; but if the mixture be exposed to the air, oxygen is absorbed, and the solution takes place.

[‡] The following account of the manufacture of red lead, from Watson's Chemical Essays, will be a satisfactory proof of this doctrine. In the manufactories of red lead in Derbyshire, the melted lead is exposed to atmospheric air; the surface soon becomes covered with a dusky pellicle; this pellicle being removed, another is formed; and thus, by removing the pellicle as fast as it forms, the greater part of the lead is changed into a yellowish green powder. This powder is then ground very fine in a mill, and, when washed and properly dried, is thrown back into the furnace, and by constant stirring for 48 hours, so as to expose every part to the action of the air, it becomes red lead, and is taken out for use. Twenty cwt. of lead generally give 22 cwt. of red lead; so that 2 cwt. of oxygen is absorbed from the atmosphere during the process.

which it absorbs oxygen in various proportions*; and one metal may not only have a greater or less capacity, but also a greater or less attraction for oxygen than another; so that one will often rob the other, thus reducing the oxide to its primitive metallic form †.

What metals are oxidized by the decomposition of water?

Iron, zinc, tin, and antimony decompose water, and become oxidized by the process. The rust which forms upon polished iron is occasioned by the iron imbibing the oxygen of the water which it decomposes ‡, as it meets it in the

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[*] This may be shown by keeping a given weight of iron-wire red hot for some time in the bowl of a common tobacco-pipe, and weighing the iron before and after it has been submitted to the experiment.

[†] Zinc, by its powerful attraction for oxygen, decomposes a great number of salts and metallic solutions, and precipitates the metal from them in a metallic form, or in the state of oxides, less oxidized than they were before. This may be exemplified by the experiment of the metallic tree, which has been attributed to Dr. Black. For the method of conducting it, see Chapter of Experiments, No. 123.

The pin-manufacurers whiten their pins on the same principle. They fill a pan with alternate layers of pins and grain tin, into which they pour a solution of super-tartrate of potass, and then boil the whole for four or five hours. In this process, the tartaric acid first dissolves the tin, and then gradually deposits it on the surface of the pins, in consequence of its greater affinity for the zinc, of which the *brass* wire is composed.

[‡] An increase of near 30 per cent. may be given to iron, by

atmosphere. This metal, when heated, decomposes water with great rapidity §.

How do these metals operate in thus decomposing water?

This effect, like most of the operations of nature, depends on chemical affinity. These metals have a greater affinity for oxygen than oxygen has for hydrogen; the oxygen of the water, therefore, unites with the metal, to form a metallic oxide ||, while the hydrogen, the other ingredient of the water, escapes in the form of gas.

Is it known what proportion of oxygen each metal requires, in order to its being converted to an oxide?

Most of the metals are capable of combining

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heating it red hot, and passing a continued stream of the vapour of water over it, when in that state. This increase of weight arises from its decomposing the water, and imbibing its oxygen.

§ The metals, which are capable of decomposing water, effect it much sooner by means of heat than without. In this case, the caloric unites with the hydrogen of the water, and carries it off in hydrogen gas; while the oxygen, the other component part of water, unites with the metal. Hydrogen requires a very large portion of caloric to give it the gaseous form. This accounts for the necessity of heat, when water is decomposed by means of some metals.

|| See the account of an experiment, page 130, which explains the operation of metals in the decomposition of water.

with different proportions of oxygen, according to the mode by which they are oxidized *.

In what instances are acids used to oxidize metals?

Many instances of this mode of forming metallic oxides might be adduced: thus, common white lead is made by exposing sheet lead to the fumes of acetous acid †; and the oxide of tin,

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* With respect to some metals, one dose of oxygen occasions the loss of their metallic splendour; a larger dose destroys that splendour entirely; and the proportion of oxygen may be increased so far as to give to the oxides an appearance altogether earthy. We have reason to believe that most of the metals are capable of indefinite degrees of oxidizement, producing oxides of various colours and possessing very different properties.

In the oxidizement of metals by acids, though there be no oxygen gas sensibly present by which it is effected, oxygen exists in the acids, also in the water, with which the acids are diluted; and the effect is owing to the passage of a portion of oxygen from one of these substances to the metal; and the increase in weight, which the metal acquires, is always equal to the weight of the oxygen absorbed. Whenever a metallic oxide dissolves in an acid, it causes the acid properties to disappear exactly as if an alkali had been employed; and saturates corresponding quantities of the different acids. Berthollet.

† The manufacture of white lead is conducted in the following manner: A number of earthen crucibles, holding from 3 to 6 quarts each, and nearly filled with vinegar, are placed in hot beds of tan; upon these crucibles thin sheets of lead, rolled up in coils, are placed, one coil over each crucible. The heat of the bed occasions the vinegar to rise in vapour, which at-

by submitting that metal to the action of the nitric acid [‡].

What are the properties *of metallic oxides ?*

They are in general friable and pulverulent; are heavier than the primitive metal ; and with the different acids form metallic salts [§].

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taches itself to the lead, and oxidizes its surface to a considerable depth. At a certain time the oxide which has been thus formed is scraped off, and the coils of lead replaced : in this manner the operation is repeated, till the whole of the metal is oxidized. This oxide, which contains a portion of carbonic acid, is afterwards *washed*, and ground for sale. See Additional Notes, No. 28; also Mr. Hume's Observations, in the Medical and Physical Journal for March 1805.

[‡] The metallic oxides readily combine with alkalies, and with some of the earths, similar to the acids. Hence originate the terms plumbate of potass, plumbate of lime, argentate of ammonia, &c. These terms, however, are certainly improper.

[§] The nature of the combination of oxygen with a metal, the subsequent solution of the metal in an acid, and its revivification, may be shown in a satisfactory manner by the following process: Take a quantity of copper filings, boil them in concentrated sulphuric acid (common oil of vitriol) with a small portion of nitric acid; and when the copper is dissolved dilute the solution with water, and set it aside to crystallize. The crystals will be the true sulphate of copper, and will exemplify the formation of a metallic salt. Then dissolve these crystals in a little water; and if the polished blade of a knife be immersed in the solution, the copper will be revived, and appear of its natural colour upon the knife. The oxygen, having a greater affinity for the iron than the copper, passes to the iron, by which the copper becomes de-oxidized, and consequently

Is it necessary to oxidize the metals that are intended to be formed into metallic salts?

All metals are incapable of dissolving in acids, until they are combined with oxygen[*]. This is a fact of great importance to be remembered; it is a truth to which there is no exception[†].

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insoluble in the acid: it therefore precipitates itself from the solution, and attaches itself to the knife in a metallic form. In the formation of sulphate of copper, the oxidizement of the metal, and its solution in the acid, seem to be only one operation; but the metal is undoubtedly first oxidized by the oxygen of a portion of acid, and *then* becomes soluble.

[*] It is not only true that all metals must be oxidized before they can be dissolved in acids, but they must contain a certain proportion of oxygen, which proportion varies according to the nature of the metal to be dissolved, and the acid that is employed. On the other hand, if a metal has combined with more oxygen than the necessary proportion, it will precipitate itself from the acid, and be incapable of forming a salt. The dyers are often perplexed by the operation of this principle. In making their solutions of tin, if they add the tin to the acid too hastily, or in too large quantities, the tin becomes, by the violent action of the acid, more oxidized than it ought to be, and precipitates itself instead of remaining in the solution. In some metallic solutions it is necessary to add a third substance, for the purpose of depriving the metallic oxide of part of its oxygen, in order to prevent a precipitation.

[†] It was formerly imagined that metallic salts could be formed with the metal in certain states of oxidizement only. Thus the salts of iron have been supposed to consist of the metal in determinate degrees of oxidizement; one, the green sulphate, containing it at the *minimum*, the other, the red sulphate, at the *maximum*; and that between these there are no intermediate com-

Is there any instance of the stronger acids being made use of by manufacturers to dissolve metals?

Yes: the manufacturers of sulphate of copper boil the oxide of copper in strong sulphuric acid, and dissolve it by that operation [‡].

What other instances are there of manufacturers using the mineral acids for dissolving metals?

Silver is frequently dissolved in nitrous acid, by the refiners, in the business of parting [§]; gold is dissolved in nitro-muriatic acid, for painting china; and the dyers use large quantities of tin dissolved in a peculiar acid prepared for that purpose [||].

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binations. But Berthollet has remarked (see *Chemical Statics*), that in the crystallization of sulphate of iron, the first crystals are nearly without colour: those which succeed in the subsequent crystallizations assume more and more colour, to a deep green; and at last there is a liquor not capable of crystallizing, and which contains the metal in the state of the highest oxidizement. This proves that some metallic salts have not fixed proportions of oxygen, but pass by insensible gradations from one state to the other. See more on this subject in Murray's Chemistry, vol. iii. page 52 to 56.

[‡] This is common blue vitriol. The mode of its manufacture may be collected from a former note.

[§] For an account of this business, consult Lewis's Commerce of the Arts.

[||] It is supposed that some hundred tons of tin are annually used in this way, by the dyers of these kingdoms.

Is it possible to recover metals which have been dissolved in acids?

The attraction of the different metals for oxygen is so various, that several of them, when dissolved, may be precipitated even in a metallic form, by the addition of metals that have a greater affinity to oxygen than the dissolved metal *.

What is the usual mode of reducing metallic oxides?

Charcoal is the agent usually employed, on account of its superior affinity for oxygen †.

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* This is exemplified by the refiners in their operations. When the silver is dissolved in aqua-fortis, they recover it by placing plates of copper in the solution. The copper absorbs oxygen from the silver, and the latter is precipitated in a metallic state. All metals have the powers of de-oxidizing gold and silver; copper will take oxygen from mercury; and iron will reduce an oxide of copper. The degree of attraction for oxygen, which the different metals possess, seems to be in the following order:—manganese, zinc, iron, tin, copper, mercury, silver, gold.

† The usual mode of procedure is to mix a quantity of charcoal with the metallic oxide, and subject the mixture to an intense heat in crucibles. The oxygen combines with the charcoal, and with a portion of caloric, and goes off in carbonic acid gas; the metal then falls to the bottom of the crucible in a button.

The reduction of metallic oxides, by mixing them with charcoal powder, and submitting them to the action of fire, probably

Are you acquainted with any other agent which is equal to the de-oxidizement of a metal?

Yes: some metals have so loose an union with oxygen, that even light ‡ will separate it, and reduce the oxide to its original metallic state §.

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gave rise to the fable of the Phœnix, which was a favourite emblem with the old chemists:

> "For, when Arabia's bird, by age opprest,
> Consumes delighted on his spicy nest,
> A filial phœnix from his ashes springs,
> Crown'd with a star; on renovated wings
> Ascends exulting from his funeral flame,
> And soars and shines, another and the same."
>
> DARWIN.

Chemists formerly had an idea that combustion cannot destroy the matter on which it operates. I have seen an old engraving of sundry chemical apparatus, with a phœnix in the midst of its flames, with this superscription:—

"Naturæ regna instar Phœnicis per ignem reviviscunt."

Of all known substances, carbon and hydrogen have the strongest attraction for oxygen. This accounts for their efficiency in de-oxidizing metallic oxides. Muriatic acid has the property of partially deoxidizing several of the metallic oxides. It has a greater affinity for oxygen than any other acid.

‡ Oxygen gas is composed of oxygen, caloric, and *light*. Without a chemical union with light it would not be in a state of gas.

§ Sennebier discovered that the rays of light have not all the same chemical effects;—that the violet rays, for example, will blacken recent muriate of silver in 15 seconds, though the red will not produce the same effect in less than 20 minutes. Respecting some other properties of light, see Additional Notes, No. 21.

Hydrogen gas will effect the same purpose, when assisted by heat*.

What oxides are there besides metallic oxides?

We are acquainted with an oxide of each of the simple combustibles†, sulphur, phosphorus, and hydrogen; with two oxides of carbon, the other simple combustible; and with two of nitrogen.

What is the origin of the oxide of sulphur?

This oxide is formed by keeping sulphur melted‡, for some time in an open vessel, whereby it absorbs oxygen from the surrounding atmosphere§.

What is the origin of the oxide of phosphorus?

If phosphorus be not preserved entirely from the access of air and light, it soon becomes first white, and then of a dark brown colour, by its

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* If the red oxide of lead be put into a receiver of hydrogen gas, and the oxide be heated by means of a glass lens, the oxygen of the metal will combine with the hydrogen to form water, and the metal will be completely revived.

† With the exception of water, all the products arising from the union of the simple combustibles with oxygen are either oxides or acids.

‡ By this operation sulphur acquires a permanent red colour. It is used in this state for taking off impressions from seals and medals.

§ According to a late analysis of Dr. Thomson, the oxide of sulphur contains 97.6 sulphur, and 2.4 oxygen. See his paper on this subject in Nicholson's Journal, 8vo, vol. vi. 92.

union with oxygen. In this state it is *oxide* of phosphorus ‖.

What is the nature of the oxide of hydrogen?

Hydrogen differs from the other three simple combustibles in being capable of combining only with one dose of oxygen; whereas *they* form acids as well as oxides. The combination of oxygen with hydrogen produces water ¶.

What is the nature of the oxides of carbon?

The first degree of oxidizement of carbon produces *carbonous* oxide, or charcoal *; a further degree of oxidizement gives it a gaseous form, and produces *carbonic* oxide.

How is carbonic oxide prepared?

Carbonic oxide, which was one of the last discoveries of Dr. Priestley, is procured by heating charcoal with metallic oxides, or earthy carbonates; by which means the charcoal absorbs sufficient oxygen to give it a gaseous form.

‖ Phosphorus, when newly prepared, always contains some oxide of phosphorus mixed with it; but this may be easily separated by plunging the mass into water heated to about 100. The phosphorus melts, while the oxide remains unchanged, and swims upon the surface of the melted phosphorus.

¶ For the nature and properties of water, see Chapter iv. page 120.

* Charcoal is composed of about 64 carbon and 36 parts oxygen; but it generally contains also a small portion of hydrogen. For the properties of charcoal, consult Chapter ix. page 321.

What is the difference in the composition of carbonic oxide *and carbonic* acid?

Carbonic *oxide* contains 60, and carbonic *acid* 82 per cent. of oxygen *.

What are the properties of carbonic oxide?

Carbonic oxide, like most other gases, is invisible and elastic; its specific gravity is somewhat less than that of atmospheric air; it is highly combustible †; but it is a gas that will not itself support combustion; neither is it fit for animal respiration ‡.

What are the oxides of nitrogen?

The first degree of oxidizement produces *nitrous* oxide; a further portion of oxygen forms *nitric* oxide. Both these oxides are in the state of gas.

What is the origin of nitrous *oxide; and how is it procured?*

Nitrous oxide is another of the gases discovered by Dr. Priestley §. It is readily procured

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* Carbonic oxide is composed of 60 oxygen, and 40 carbon. Carbonic acid 82 oxygen, and 18 carbon.

† Carbonic oxide burns with a lambent blue flame in atmospheric air; but it burns with more rapidity and brilliancy when mixed with oxygen gas.

‡ According to some French chemists, birds drop down dead immediately on being put into this gas. These chemists attempted to breathe it themselves; but it produced giddiness and faintness. Ann. de Chim. xxxix. 56.

§ Priestley discovered this gas about the year 1776, and by exposing crystals of nitrate of ammonia in a retort, to the heat of a lamp[‖]; by which means the ammoniacal salt is decomposed, and this gas evolved.

What are the properties of nitrous oxide?

This gas bears the nearest resemblance of any other to atmospheric air. It will support combustion even better than common air; is respirable for a short time[¶]; is absorbed by wa-

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called it *dephlogisticated* nitrous gas. For further information respecting its properties consult *Davy's Researches.* Mr. Davy investigated it with great care, and pointed out its nature and properties.

[‖] The heat should not be less than 340°, nor above 400°. One pound of dry nitrate of ammonia, well decomposed, will produce rather more than four cubic feet of air, or about 32 gallons wine measure.

Nitrous oxide, or the gaseous oxide of nitrogen, as it is sometimes called, is composed of 63 nitrogen, and 37 oxygen.

[¶] Persons who have inhaled this gas have felt sensations similar to those produced by intoxication. Its effects on some people are truly ludicrous, producing involuntary muscular motion, and a propensity to leaping and running; on others, involuntary fits of laughter; and in all, high spirits, and the most exquisitely pleasurable sensations, without any subsequent feelings of debility. When Mr. Robert Southey, the poet, inhaled it, he declared that it produced in him sensations perfectly new and delightful; and for several hours afterwards he imagined that his taste and smell were more acute than usual. In a poetical rhapsody, he remarked, that he supposed the atmosphere of the highest of all possible heavens must be composed of this gas. See Davy's Researches, and Nicholson's Journal, vol. iii. 4to, 446.

From its highly stimulant powers, this gas has been applied ter; and is capable of forming salts of a peculiar nature, by its combination with alkalies. Its spec. grav. is much greater than that of common air.

What is the origin of nitric *oxide; and how is it procured?*

Nitric oxide, or nitrous gas, as it has usually been called, was also discovered by Dr. Priestley, during some of his first experiments on air*. It is procured by digesting copper or mercury in diluted nitrous acid, and collecting the gas which rises during the solution.

What are the properties of nitric oxide?

Nitric oxide is an invisible gas, which assumes

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with advantage to the treatment of several diseases of debility; but I question whether it be more serviceable than pure oxygen gas diluted with atmospheric air, as ordered by Dr. Thornton, and some other physicians.

* This gas was used by Dr. Priestley for purposes of eudiometry. The first eudiometer was made in consequence of his discovery, that when nitrous gas is mixed with atmospheric air over water, the bulk of the mixture diminishes rapidly, in consequence of the combination of the gas with the oxygen of the air, and the absorption of the nitric acid, thus formed, by the water. Whenever nitrous gas is thus mixed with atmospheric air, the diminution will be in proportion to the quantity of the oxygen; of course this gas will always indicate the measure of oxygen present in any portion of air submitted to trial. In consequence of some inconveniences attending the use of this eudiometer, others have been invented by Scheele, De Marti, Humboldt, Seguin, Berthollet, and Davy. An account of their different processes may be seen in Dr. Thomson's Chemistry, vol. iii. 305.

an orange colour whenever it comes in contact with atmospheric, or any other air that contains oxygen †. It produces suffocation in those animals who attempt to breathe it, though some substances will burn in it ‡. Its specific gravity is somewhat more than that of common air.

What compounds are formed by means of nitric oxide?

Nitric oxide gas, when mixed with oxygen gas, forms nitric *acid.* The aqua-fortis of commerce owes its colour to this gas.

What other oxides are you acquainted with?

The red part of the blood of animals is an oxide; and sugar is a vegetable oxide. Moreover oils §, butter, and dried salt meats, become rancid

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† Nitric oxide is composed of 57 oxygen, and 43 nitrogen, oth by weight. Nitric *acid* is composed of 75 oxygen and 25 nitrogen.

‡ If phosphorus be previously inflamed, it will continue to urn in this gas with as much splendour as in oxygen gas.

Dr. Priestley found, by experiment, that 100 measures of niric acid, of a moderate strength, absorbed in two days 90 of itrous gas: that when about 7 parts were absorbed, the acid ssumed an orange colour, when 18 parts were absorbed a reen colour, and when the 90 were combined it became red nd fuming.

§ Seed oils are sometimes oxidized artificially for the puroses of painting. Linseed oil is thus boiled with the red oxide f lead. In this operation, the oxygen of the metal combines vith the oil, imparting to it the property of drying quickly. Oil hus prepared is called *drying* oil.

by absorbing oxygen from the atmosphere; so that oxygen not only performs for us an infinite number of valuable and important offices, but appears to be one of the grand agents of decomposition and destruction *.

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* All organized beings, whether vegetable or animal, possess the materials of which they are composed only for a limited time: life itself is a boon which is only *lent*, to serve the purposes of infinite beneficence. At the proper period, *oxygen*, or some other powerful agent, effects the decomposition of the curious fabric, and sets all the elementary particles at liberty, to form other equally perfect and complicated existencies[1],

> "Which *thus*, alternating with death, fulfil
> The silent mandates of the ALMIGHTY'S will;
> Whose hand, unseen, the works of nature dooms,
> By laws unknown,—WHO GIVES AND WHO RESUMES."
> DARWIN.

[1] See Additional Notes, No. 26.

CHAP. XII.

OF COMBUSTION.

What is combustion?

Combustion [*] is a process by which combustible bodies decompose oxygen gas, absorb its base [†], and suffer its caloric to escape in the state of sensible heat.

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[*] Lavoisier and other French chemists defined combustion to be the combination of any body with oxygen. This definition, however, has very properly been objected to; for there are many instances of oxygen combining with a body without producing combustion. Indeed, this union is sometimes effected when no combustion can possibly take place. Oxygen often combines with bodies without any sensible extrication of heat or light; but we never, in common language, give the name of combustion to any operation in which heat and light are not liberated.

[†] To render the explanation of this process more perspicuous, it may be said, that oxygen exists in the state of gas in atmospheric air; that when a combustible is heated to a certain degree, it possesses such an attraction for oxygen, that it absorbs it from the air and fixes it in a solid form; while the light and caloric, the solvents which gave it the gaseous state, escape and diffuse themselves among the surrounding bodies. See Additional Notes, No. 36 and 38.

Are all substances capable of being burnt?

No: some substances are combustible[*], others incombustible.

How are combustible bodies classed by chemists?

Into simple combustibles, compound combustibles, and combustible oxides[†].

What do you mean by SIMPLE *combustibles?*

Those combustible substances that have resisted every attempt to decompose them, are called simple combustibles[‡].

Endeavour to enumerate the simple combustibles.

The simple combustibles with which we are acquainted, are hydrogen, sulphur, phosphorus,

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[*] The term, *combustible*, is applied to every body that is capable of being burnt in atmospheric air, or in oxygen gas, and, consequently, of uniting with oxygen.

[†] The combustible oxides consist of combinations of the combustible bodies, which have not undergone combustion, or their compounds, with oxygen. This class of bodies is very numerous, as it includes the greater part of animal and vegetable substances. The great combustibility of combustible oxides is probably owing to the weaker affinity by which their particles are united. Hence, they are more easily separated than homogeneous particles, and of course combine more readily with oxygen. Those simple combustibles which melt easily, or which are in the state of elastic fluids, are also very combustible, because the cohesion between their particles is easily overcome. Dr. Thomson, in Nicholson's Journal for 1802.

[‡] For an account of the nature and properties of the simple combustibles, see Chap. ix. page 304.

carbon, and all the metals§, except gold, silver, and mercury.

What are COMPOUND *combustibles?*

Compound combustibles are all such as are formed by the union of two or more of the simple combustibles ||. Common coal is an instance of this combination ¶.

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§ We may be satisfied that metals are really combustible, by repeating the following simple and beautiful experiment of Dr. Ingenhousz:—"Twist a small iron wire into the form of a corkscrew, by rolling it round a small stick: fix one end of it into a cork (which will fit a glass jar previously filled with oxygen gas), and lap round the other end a small bit of cotton thread dipped in melted tallow. Set fire to the cotton, and immediately plunge the whole into the jar of oxygen gas. The wire will take fire from the cotton, and burn with great brilliancy, throwing out very vivid sparks in all directions. During the combustion, the iron combines with the oxygen, which was in the jar, and is converted into an oxide, with an augmentation in weight of 35 per cent." Mr. Accum says, that a thick piece of iron or steel, such as a file, may be burned in oxygen gas, if it be made very sharp-pointed, and a small piece of wood be stuck upon its extremity and set fire to previous to its being immersed in the gas. The method of suspending the metal in the jar may be seen in plate 4, fig. 17, of Lavoisier's Elements.

|| The compound combustibles are arranged by Dr. Thomson under the five following heads: 1st, sulphurets; 2d, phosphurets; 3d, carburets; 4th, alloys; 5th, sulphuretted, phosphuretted, and carburetted hydrogen.

¶ Hydrogen and carbon, intimately united in the capillary tubes of vegetables, form bitumens, oils, and resins, which are compound combustibles. See Additional Notes, No. 39.

What substances are there which are incombustible?

We are acquainted with thirteen incombustible substances; viz., nitrogen*, the three alkalies, and the nine earths†.

What is the nature *of combustion*‡?

Combustion appears to be a double decomposition §, in which the combustible and the

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* Perhaps nitrogen might be called a *combustible* body, as by means of electricity it combines with the base of oxygen gas, forming nitrous acid.

† Some of the alkalies and earths possess certain properties in common with combustibles, and are capable of exhibiting phænomena somewhat analogous to combustion. These have been described under the title of *semi-combustion;* but for particulars I must refer the reader to Dr. Thomson's Theory of Combustion, in Nicholson's Journal for 1802.

‡ To the old chemists the process of combustion was quite inexplicable; its nature, indeed, was not at all understood till within these thirty years. It is now known to be merely a play of affinities between oxygen, light, caloric, and the base of the combustible body; so that nothing is really lost, but new modifications of the same ingredients take place.

§ Dr. Thomson's account of combustion will convey to the reader a clear idea of this natural phænomenon.—"When a stone, or brick, is heated, it undergoes no change except an augmentation of temperature, and when left to itself it soon cools again, and becomes as at first. But with combustible bodies the case is very different. When heated to a certain degree in the open air, they suddenly become much hotter of themselves, continue for a considerable time intensely hot, sending out a copious stream of caloric and light. This emissupporter of combustion divide themselves each into two portions, which combine in pairs; the one forming the product, the other the fire which escapes ||.

What do you mean by SUPPORTERS *of combustion?*

The substances which are called supporters of combustion are not of themselves combustible, but are necessary to the process; that is, no

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sion after a certain period begins to diminish; and at last ceases altogether. The combustible body has now undergone a most complete change; it is converted into a substance possessing very different properties, and no longer capable of combustion. The product is incombustible, because its base being already saturated with oxygen cannot combine with any more. M. Lavoisier fully established the existence of this general law—that 'in every case of combustion oxygen combines with the burning body.' Oxygen does not combine with a combustible body till its temperature is raised; but when a combustible body is raised to a certain temperature, it begins to combine with the oxygen of the atmosphere, and this oxygen during its combination lets go the caloric and light with which it was combined while in its gaseous state." Dr. Thomson, vol. i. 417.

|| The component parts of the oxygen which is furnished by the supporters of combustion are two; viz. *oxygen* and *caloric*: the component parts of all combustibles are likewise two; viz. the *base* and *light*. If the two first are called No. 1 and 2, and the two latter No. 3 and 4, the product of combustion will be formed by the union of No. 1 and 3, and the compound, which we call fire, will arise from the combination of No. 2 and 4. Dr. Crichton, I believe, was the first chemist who gave this view of combustion; and in his public lectures elucidated the theory, by many appropriate experiments.

combustion can ever take place without one or other of the supporters of combustion being present*.

What substances are deemed supporters of combustion?

There are only seven known supporters of combustion; viz., oxygen gas†, atmospheric air, nitrous oxide, nitric oxide, nitric acid‡, oxygenized muriatic acid, and hyper-oxygenized muriatic acid§.

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[*] For a further elucidation of this subject, consult Dr. Thomson's Essay on Combustion, in Mr. Nicholson's Philosophical Journal for 1802.

[†] If oxygen gas be forced out of a bladder, or a gasometer, upon a piece of ignited charcoal, the combustion will be so much increased, that the light thrown off will be too vivid for the eye to endure. Rock-crystal that has been exposed to an intense heat, in atmospheric air, for a very long time, and has suffered nothing in its hardness, transparency, or any other quality, will fuse like other substances, when submitted to a stream of oxygen gas.

[‡] If nitrous acid be mixed with about half its weight of sulphuric acid, and poured into a little oil of turpentine, the whole will immediately burst into flame. In this experiment it is the oxygen of the nitric acid which promotes the combustion.

[§] To the above list of supporters might be added *water*; for it is well known that water in many cases promotes and accelerates combustion. It appears that the ancients were acquainted with this property of water: hence the invention of the æolipyle, which was much in use formerly. Dr. Plott, in page 433 of his History of Staffordshire, mentions a curious

What is it that imparts to these various bodies the peculiar property of supporting combustion?

The principle common to all these substances is OXYGEN; it is therefore to oxygen alone || that they are indebted for this property.

Is it known how oxygen supports combustion?

The agency of oxygen in combustion is attributable to its affinity ¶ for combustible bodies. For whenever such bodies are ignited, in circumstances favourable to combustion, they absorb oxygen from the atmospheric air, or other contiguous substances, till the combustible is converted to an incombustible body.

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instance of the employment of this instrument. He says, that the lord of the manor of Effington is bound by his tenure to drive a domestic fowl every new-year's-day three times round the fire in the hall of the lord of Hilton, while Jack of Hilton (a brazen figure having the structure of an æolipyle) blows the fire. I believe this grotesque figure is still preserved at Hilton; a drawing of it may be seen in the thirty-third plate of Plott's Staffordshire. The Heathen priesthood employed this instrument in working sham miracles. Some of the ancient Saxon and German idols were of this construction.

|| As oxygen gas contains the caloric which is liberated during combustion, we have reason to suppose that all the supporters of combustion contain caloric combined with their oxygen, as an essential ingredient in their composition.

¶ Combustion, like all other chemical processes, may be explained by the laws of chemical affinity. The combustible having a greater affinity to oxygen than oxygen has to caloric, the oxygen gas is decomposed, and its oxygen combines with the ignited body, while its caloric, becoming free, produces the

From whence proceeds the heat which we observe during combustion?

In general, the heat produced by combustion arises from the oxygen gas of the atmosphere*; for, as the oxygen combines with the combustible body, it disengages the caloric which it held when in the state of atmospheric air.

Can you explain this operation with more precision?

The act of combustion effects a real analysis of atmospheric air; for while the oxygen combines with the combustible, the caloric, in the form of sensible heat, is thrown off in every direction†.

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heat which is diffused among the surrounding bodies. As the oxygen unites with the combustible, it becomes more dense than it was when in the state of gas, consequently it has less capacity for caloric than it had; a portion of it, therefore, must be given out before the oxygen can combine with the new substance that attracts it from its former combination.

* Though every case of combustion requires that heat should be evolved, yet this process proceeds very differently in different circumstances. Hence the terms *ignition, inflammation, detonation,* &c.

† The rapid combustion that is occasioned by inflaming combustible substances, mixed with oxy-muriate of potass, is owing to the large quantity of oxygen contained in that salt, and which it holds by a weak affinity; and also to a large portion of caloric which this singular substance contains in union with its oxygen, and which is given out, while the oxygen enters into combination with the combustible. See Note, page 269.

Does this account for the long continued heat which we experience in every common combustion?

Whenever we burn a combustible body in order to procure heat, a continued stream of atmospheric air flows towards the fire-place[‡] to occupy the vacancy left by the air that has undergone decomposition, and which in its turn becomes decomposed also[§]. Hence a supply of caloric is furnished, without intermission, till the whole of the combustible is saturated with oxygen.

[‡] On some parts of the continent rooms are warmed by stoves that have ash-pits without; so that the combustion is kept up by air which has no connection with the air of the room; consequently there is no current, nor is the air of the room contaminated; and the persons who occupy them are not subject to the inconvenience of those cold draughts of air which render some of our rooms that have large fire-places dangerous and unhealthy.

[§] Argand's lamp is constructed upon this principle, that a current of air hastens combustion: for in consequence of this perpetual supply of oxygen the air is renewed every moment, and produces heat sufficient to burn the smoke as it is formed. The smoke which arises from a common fire is chiefly water in the state of vapour, with a mixture of carburetted hydrogen and bituminous substances; part of the water comes from the moisture of the fuel; the other part is formed during combustion, by the union of the hydrogen of the combustible with the oxygen of the atmosphere. What takes place in a common fire would furnish an intelligent parent with matter for several interesting conversations, which could not fail to rouse the curiosity and contemplation of his pupil. See Additional Notes, No. 16.

What other effects are produced by combustion?

As the combustible burns, LIGHT is disengaged, and the more subtile parts of the combustible, now converted by caloric into gas, are dissipated in that state*. When the combustion is over, nothing remains but the earthy parts of the combustible, and that portion which is converted to an oxide or an acid by the process †.

From whence proceeds the light which you say is disengaged during combustion?

It is now generally supposed that the light and flame which appear during this process proceed from the combustible body ‡: though some

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* Part of the caloric, which is furnished by the supporters of combustion, generally combines with part of the combustible, and converts it into gas, as has been beautifully expressed by Dr. Darwin:—

> "Thus heat, from chemic dissolution springs,
> And gives to matter its eccentric wings;
> With strong repulsion parts the exploding mass,
> Melts into lymph, or kindles into gas."

† The product of combustion is always either an *oxide*, or an *acid*, or both.

‡ If the light arose from the decomposition of oxygen gas, those combustibles which absorb most oxygen, would give out most light; but this is not the case. Pure hydrogen in burning combines with more oxygen than any other body, and gives out more heat; yet the light is barely perceptible. Several instances might be adduced, in which the quantity of oxygen combining with the combustible, during this process, is greatest where the light is smallest.

The existence of light as a constituent part of combustible chemists imagine that the light comes in part from the decomposition of atmospheric air §.

What is the origin *of light?*

Light, which is an extremely attenuated fluid matter, is constantly transmitted from the sun to

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bodies, seems to have been proved by the experiments of Deiman, Pacts, and others. These chemists exposed a mixture of sulphur and zinc to a high temperature, without any substance being present from which they could derive oxygen. At the instant when the sulphur and zinc formed a *sulphuret,* there was a vivid emission of light; and when the materials were examined, it was found that no oxidizement had taken place. On this subject, see Mr. Portal's remarks, Phil. Mag. vol. xv. p. 207. Also Thomson's Fourcroy, vol. i. 190. See Note, page 428.

"That a great part of the light comes from the combustible, is evident from the colour of the light generally varying according to the nature of the combustible. Carbonic acid burns with a blue flame, carburetted hydrogen with a white, charcoal with red, and sulphur with blue or violet." Dr. Thomson. That lime contains light is well known. If quick-lime be slacked in the dark, the liberation of light will be very evident. That light is a real substance, and can become concentrated in bodies, is evident from the properties of phosphorus. But it may also be satisfactorily shown by shutting a person up in a dark room, and directing him to put one of his hands out for a short time into the sun's rays, and then to draw it back into the dark; when he will be able to see that hand distinctly, and not the other. See Additional Notes, No. ~~[illegible]~~ 40; also a note, page 318.

§ The following fact seems to prove that atmospheric air contains light. Some time ago a soldier in the French army found that heat was produced by the condensation of the air the earth*. It is also found combined with several terrestrial substances †.

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in an air-gun. The experiment has lately been repeated before the National Institute. If the air be very rapidly compressed, heat is disengaged by the first stroke of the piston, sufficient to set fire to a piece of fungus match placed within the pump. If the end of the pump be furnished with a glass lens which admits of the inside being seen, at the first stroke of the piston a ray of *vivid brilliant light* will be perceived. See Note, page 132.

Light is generally given out, whenever oxygen combines with any body; oxygen therefore is scarcely ever extricated without the agency of light.

* Light is transmitted to us from the sun, accompanied with caloric, in little more than eight minutes, which is a velocity almost equal to 200,000 miles in a second of time; but the rays of light and the rays of caloric are distinct from each other. It has been demonstrated that some rays from the sun produce heat, which have no power of communicating light. For a further elucidation of this subject see a paper by Dr. Herschel in the Philosophical Transactions, and an account of the experiments of Sir Henry Englefield in the first volume of the Journals of the Royal Institution. The velocity of light will appear truly astonishing, when we consider that were a cannon-ball thrown from the sun, and, travelling with the same velocity that it acquires when first shot from the cannon, it would be more than thirty years in arriving at this earth.

† Light is capable of entering into bodies, and of being afterwards extricated without any alteration. It also combines with them, and forms one of their component parts. On this subject consult Dr. Hulme's paper in the Philosophical Transactions for 1800 and 1801; Dr. Herschel's paper in the former of these volumes, and Dr. Wollaston's in the volume

What is the nature *of light?*

Light is a peculiar substance, the nature of which is little understood[‡]; but it possesses several very singular and striking properties[§].

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for 1802; all which are extremely interesting. See also Mr. Henry's observations in the fifth volume of the Manchester Memoirs. From the following beautiful apostrophe to Light, by Milton, there is some reason to imagine, that even in his time some idea was entertained of light being latent in bodies:—

> "Hail, holy light! offspring of Heaven first born,
> Or of th' Eternal co-eternal beam,
> Bright effluence of bright essence increate——
> Thy fountain who shall tell? Before the sun,
> Before the heavens thou wert; and at the voice
> Of God, as with a mantle, didst invest
> The rising world of waters dark and deep."

[‡] Sir Isaac Newton described light to be a substance consisting of small particles, constantly separating from luminous bodies, moving in straight lines, and rendering bodies luminous by passing from them and entering the eye. Those who wish to become acquainted with all the known properties of light, such as the refraction, reflection, inflection, &c. of its rays, may consult Newton's Optics, Fourcroy's System of Chemical Knowledge, and the several papers by Herschel and count Rumford, in the Philosophical Transactions.

[§] Light is decomposable into seven distinct rays of different colours. Some bodies absorb one coloured ray, others another, while they reflect the rest. This is the cause of colour in bodies. A red body, for instance, reflects the red rays, and absorbs the rest. A white body reflects all the rays, and absorbs none; while a black body, on the contrary, absorbs all the rays, and reflects none. Dr. Paley has remarked, "that if light had been made by a common artist, it would have been of one uniform colour; whereas, by its present composition, *Is the presence of atmospheric air necessary to combustion?*

Combustion cannot take place in a vacuum; no combustible body can burn without atmospheric air, or at least without oxygen, which is a component part of atmospheric air*.

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we have that variety of colours which is of such infinite use to us for the distinguishing of objects; which adds so much to the beauty of the earth, and augments the stock of our innocent pleasures."

"Nature's resplendent robe!
Without whose vesting beauty all were wrapt
In unessential gloom."

Light has great effect on vegetation. See a Note, page 34[illegible]. It also possesses the property of deoxidizing several of the metallic oxides, by combining with their oxygen, to which it gives wings, as it were, to fly off in the form of gas.

The glow-worm seems to have the faculty of absorbing light and giving it out at pleasure:—

"Sweet child of stillness, midst the awful calm
Of pausing Nature thou art pleas'd to dwell,
In happy silence to enjoy thy balm,
And shed through life a lustre round thy cell."

Dr. Walcott.

In the Asiatic Annual Register for 1802, we are told that there is a sparrow of Hindostan, that has the instinct to light up its nest in the night-time with glow-worms, which it collects for this purpose; and that it attaches them to the inside of its nest by means of a tenacious kind of clay. See Additional Notes, No. 40.

There is an insect common in the United States, called the *lightning bug*, that is seen sometimes in considerable numbers, shedding its intermitting light, on summer evenings, in the fields and gardens.

* This may be demonstrated by placing a lighted candle un-

In what do combustible bodies differ from each other?

Combustible bodies differ from each other principally in the rapidity with which they absorb oxygen, and in the proportion of it which they † can take up, to form the new compound.

What is the effect of these properties, in the act of combustion?

The greater the portion of oxygen gas which any combustible body is capable of decomposing, the greater will be the heat that is produced by the combustion.

How is it known that oxygen unites with the combustible body in the act of burning?

If a combustible substance be burnt in a sufficient quantity of vital air in a close vessel, and the product preserved, the whole will be found

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der a glass jar, inverted upon a plate of water. It will be seen that the candle will go out as soon as it has consumed all the oxygen contained in the included air.

† Almost all the simple substances are capable of combining with various doses of oxygen. Thus sulphur forms oxide of sulphur, sulphurous acid, and sulphuric acid; phosphorus forms oxide of phosphorus, phosphorous acid, and phosphoric acid; carbon also unites with different portions of oxygen and forms carbonous oxide, carbonic oxide, and carbonic acid. When either of these simple combustibles is united to any other, or to either of the alkalies, earths, or metals, the combinations are known by names ending in *uret*, as sulphuret of potass, phosphuret of lime, carburet of iron, &c.

to be increased in weight[*] exactly in proportion to the oxygen gas consumed; and the combustible body will then have become incombustible[†].

What is the cause of a body becoming thus incombustible?

Because when a body is fully burnt it is saturated with oxygen; at least as far as combustion can saturate it; it, therefore, cannot combine with any more: but some bodies may be rendered combustible again, by depriving them of the oxygen which they absorbed in their former combustion[‡].

In the decomposition of atmospheric air by combustion, what becomes of the nitrogen gas?

As the oxygen becomes fixed in the combusti-

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[*] Phosphorus is an eminent instance of this increase by combustion. If an ounce of phosphorus be properly inflamed, it will produce more than two ounces of phosphoric acid; the increase in weight arises from its absorption of oxygen.

[†] A series of curious experiments of this kind may be seen in Lavoisier's Chemical Elements, 495, and following pages, fourth edition.

[‡] "This view of combustion authorises us to divide almost all the productions of nature into two grand classes; one of *combustible* bodies, the other of bodies already *burnt:* in the masses and action of the former we discern the causes of inflammable meteors, the perpetual alteration of the surface of the earth, volcanos, &c.; in the existence of the latter we perceive the source of the number and diversity of acids, saline compounds, oxides, and metallic salts, which vary in a thousand ways the appearance of ores, &c." Fourcroy.

ble body, its caloric is disengaged; part of which combines with the nitrogen, and carries it off in the form of rarefied nitrogen gas.

What chemical name is given to burnt bodies?

Such substances are said to be *oxygenized,* or *oxidized;* that is, changed into acids, or oxides §.

Does the oxygen become fixed in all combustible bodies when burnt?

It is a characteristic property of a combustible body to form a chemical combination with the oxygen, that is furnished by the supporters of combustion. The oxygen acquires such density by this process, that it is often extremely difficult to separate it again from the oxide ‖.

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§ Whenever a substance is converted to an oxide, we say it is *oxidized;* but if it becomes an acid, by its union with oxygen, we say, it is *oxygenized.* We are indebted to Mr. Chenevix for this lucid definition of terms, too often used indiscriminately.

‖ When oil is burnt in an Argand's lamp, its carbon unites with the oxygen of the atmosphere, and forms carbonic acid gas; while its hydrogen unites with another portion of oxygen, and forms water. Every 100 ounces of oil thus burnt produce 130 ounces of water. In these products of combustion the oxygen is more intimately combined than it was with caloric in the gaseous state. Hence we see what a beautiful series of changes and modifications the elements of matter are destined to undergo, and how admirably Nature has provided for the preservation of all her productions.

> " To me be Nature's volume broad display'd;
> And to peruse its all-instructing page,
> My sole delight."

Is it possible to separate entirely the oxygen from burnt bodies?

Yes: bodies may be deoxidized in various ways[*]; and in some cases the oxygen may be transferred from the burnt body to a fresh combustible body, and be made the means of producing a fresh combustion; or it may in many cases be completely separated, and shown in its primitive or gaseous state[†].

What part of bodies is it which is destroyed by combustion?

No part that we know of. We have reason to think that every particle of matter is indestructible, and that the process of combustion[‡] merely

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That the combustion of alcohol produced water was known in the time of Boerhaave. By presenting a cold vessel to the flame of alcohol he collected water that was without taste or smell, and in every respect like distilled water.

[*] Water is a product of combustion, and its base is hydrogen, the most combustible substance we are acquainted with. To restore the combustibility of the hydrogen, we have only to abstract its oxygen; which may readily be done, by mixing iron or zinc filings, and sulphuric acid, with the water; the metal becomes oxidized, and the hydrogen gas is evolved as combustible as ever.

[†] This is frequently done for the purpose of procuring oxygen gas. The oxide of manganese, or of mercury, is exposed to a proper degree of heat, and the gas received in a suitable apparatus, as it is extricated.

[‡] The following concise account of the theory of combustion I copy from Berthollet. "When bodies are burnt, none

decomposes the body, and sets its several component parts at liberty to separate from each other, and to form new and varied combinations §.

What is the natural inference from this interesting fact?

The natural conclusion is, that nothing less than consummate wisdom could have devised so beautiful a system, and that nothing short of infinite power could have so modified matter as to subject it to the operation of such laws—laws that effect so many desirable purposes, and at the same time so effectually prevent the destruction of those elementary principles, which

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of their principles are destroyed; they had previously formed together one kind of compound, and they now separate from each other, at the high temperature to which they are exposed, in order to form others, with the vital air in contact with them: such of the principles as cannot unite with the vital air, that is the earth, some saline and some metallic particles, compose the cinder. The new compounds formed, are carbonic acid, or fixed air and water: the proportion of these varies according to the proportion of the carbonic particles, and of the hydrogen that had been contained in the inflammable body." Vol. i. page 163.

§ "It was said of old, that the Creator *weighed* the dust, and *measured* the water, when he made the world. The first quantity is here still; and though man can gather and scatter, move, mix, and unmix, yet he can destroy nothing: the putrefaction of one thing is a preparation for the being, and the bloom, and the beauty of another. Something gathers up *all* fragments, and nothing is lost." Robinson. See Additional Notes, No. 37.

are actually essential to the preservation of the world*.

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* The indestructibility of matter is beautifully expressed in the following lines by Dr. Darwin:—

"Hence when a monarch or a mushroom dies,
Awhile extinct the organic matter lies;
But, as a few short hours or years revolve,
Alchemic powers the changing mass dissolve;
Emerging matter from the grave returns,
Feels new desires, with new sensations burns;
With youth's first bloom a finer sense acquires,
And LOVES and PLEASURES fan the rising fires."

CHAP. XIII.

OF ATTRACTION, REPULSION, AND CHEMICAL AFFINITY.

What is attraction[*] *?*

Attraction is an unknown force, which causes bodies to approach each other[†].

Which are the most obvious instances of attraction?

The gravitation of bodies to the earth; that of the planets towards each other[‡]; and the attractions of electricity and magnetism[§].

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[*] In compiling this chapter, I have availed myself, not only of Dr. Thomson's and other systems of chemistry, but also of Dr. Duncan's Introd. to the New Edinburgh Pharmacopœia.

[†] Attraction has, by some philosophers, been attributed to an inherent property of matter, and by others to the influence of some foreign agent. The former is perhaps the most probable supposition.

[‡] Sir Isaac Newton demonstrated, that the planetary attraction is the same principle as gravitation. To this principle we are indebted for the periodical flux and reflux of the tides, and for other important operations of nature.

"For this the moon thro' heav'n's blue concave glides,
And into motion charms th' expanding tides;
While earth impetuous round her axle rolls,
Exalts her wat'ry zone, and sinks the poles." FALCONER.

[§] For some account of magnetism see Note †, page 383. In

Are you acquainted with other instances of attraction?

Yes: attraction subsists between the *particles** of bodies; and it is this kind of attraction which comes under the more immediate cognisance of chemists †.

How is this kind of attraction defined in chemical language?

Whenever the force of attraction operates between particles of the same species, it is called

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addition to that, it may be remarked, that if a steel needle be rubbed *from* its eye, *to* its point, a few times over the north pole of a magnet, and then stuck in a small cork, to swim on water; the eye will veer towards the north, and the point to the south. In this way the Chinese form their mariner's compass; a guide on which they can rely at all times with perfect safety.

> "So turns the faithful needle to the pole,
> Tho' mountains rise between, and oceans roll."

* If common flowers of sulphur and potass be mixed and thrown into water, the sulphur will separate, and the potass be dissolved: but if they be previously melted together, the union will then be so perfect, that the compound will be completely soluble. The design of this experiment is to show that chemical affinity has no sensible action but on the mere elementary particles of bodies.

† All the operations of chemistry are founded on the force of attraction which nature has established between the particles of bodies, and by which force all bodies cohere. The art of chemistry employs different means to destroy this attraction of cohesion, and to form fresh substances by the means of new attractions. Take silex as an instance:—In this earth the attraction of cohesion is so strong that the most powerful acids

the attraction of *cohesion*‡; or the attraction of *aggregation*; but when between the particles of different substances, it is called the attraction of *composition*, or chemical *affinity* §.

(one excepted) have no action upon it. But if the strength of this cohesion be broken by fusing it with an alkali, it then becomes obedient to some of the other acids, and may be held in solution by them.

Klaproth found, that the ruby and the adamantine spar are scarcely affected by any chemical agent; but that if their cohesion be destroyed, they are then acted upon, and their analysis can be accomplished.

‡ It is from the attraction of cohesion that a drop of water is always spherical, and that small particles of quicksilver are constantly of a globular figure. In consequence of the same species of attraction, particles of water and other liquids ascend in capillary tubes. If a small plate of glass be laid upon a globule of mercury, the globule, notwithstanding the pressure, continues to preserve its round figure. If the plate be gradually charged with weights one after another, the mercury becomes thinner and thinner; but as soon as the weights are removed, its globular figure is restored.

§ A piece of loaf sugar broken into fine powder, or water in the state of vapour, is said to have its attraction of aggregation broken; but the smallest atom of the powder is still sugar, and the most trifling portion of the vapour is still water. In order to exemplify the latter kind of attraction, a little caustic soda may be put into a glass, and muriatic acid added to it. Both these are corrosive substances; but the compound resulting from them will be found to be our common table salt. Here we have an instance of two heterogeneous bodies producing by their action on each other a distinct substance, possessing the properties of *neither* of the bodies which com-

Can you explain with more precision what is meant by attraction of aggregation[*]*?*

The particles of all bodies are possessed of the inherent property of attracting each other; which causes them to adhere, and preserves the various substances around us from falling in pieces. The nature of this wonderful property is entirely unknown.

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pose it. See Additional Notes, No. 11. Also several instances of chemical affinity in the chapter of Instructive and Amusing Experiments.

If several salts be dissolved in the same water, when they crystallize, each particle will find its own kind by a sort of innate polarity. To prove this, dissolve separately equal weights of sulphate of copper and crystals of nitrate of potass in sufficient quantities of boiling water; pour them together while hot into a flat pan, and when the water has evaporated a little, and the whole is suffered to cool, the salts will shoot:—the sulphate of copper in blue, the nitre in white crystals, similar to what they were before they were dissolved.

[*] There are different kinds of aggregation; viz. solid, soft, liquid, and gaseous. A stone is an instance of the first, jelly of the second, water of the third, and atmospheric air of the last.

If we carefully notice two small particles of mercury, while gently moved along a smooth surface towards each other, a mutual attraction of one to the other will be very evident at the moment of their union into one globule. Two small pieces of cork floating in a bason of water, if not nearer to the edge than to each other, will visibly approach, and at last come into contact.

The force of the attraction of aggregation, in solid bodies, *What do you understand by attraction of composition, or chemical affinity?*

The particles of every simple substance have not only an attraction among themselves, forming the aggregation of that body or substance; but they have also another attraction to such other substances with which they have an affinity; and, when presented, unite to them, and form a new compound†.

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may be measured by the weight necessary to overcome it. Thus, if a rod of metal, glass, wood, &c. be suspended in a perpendicular direction, and weights be attached to its lower extremity till the rod break, the weight attached to the rod just before it broke, is the measure of the cohesive force of the rod.

† This power was by Bergman called *elective* attraction, as though matter were endued with the ability to prefer one substance to another. *Chemical affinity* is a more definite term, and is now in general use.

Those substances which are capable of uniting, are said to have a chemical affinity for each other; those which do not form a chemical union, are said to have no affinity. The varied influence of this property of matter may be attributed by the atheist to *chance*; but the man of sober reflection, who allows the evidence of a mass of facts to have its natural influence upon his mind, will be persuaded that chemical affinity can neither be ascribed to accident, nor to a necessity in the nature of things; for, perceiving that the works of nature and art are all governed by this astonishing principle, he will attribute the whole to the contrivance, to the wisdom, and to the goodness of an intelligent Agent, who has varied these operations in a thousand ways, to suit the designs of his beneficence, and to promote different and distinct purposes of utility and happiness.

What are the laws of chemical affinity[*]*?*

Chemical affinity can only exist between the particles of opposite and distinct substances; and this species of attraction is exerted with different force, according to the nature of such substances, and frequently in proportion to the mass. Most bodies combine only in certain proportions[†]:—the new combinations acquire new properties[‡], and are incapable of separation by mechanical means.

How are the different kinds of chemical affinity distinguished?

Chemical affinity is of three kinds; viz., simple affinity, compound affinity, and disposing affinity.

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[*] There are several laws of chemical affinity; but these may be studied with more effect when the first elements of the science are understood. They are well explained by Fourcroy, in his System of Chemistry, vol. i. 96, &c.

[†] Thus oxygen and hydrogen combine only in one proportion, and the result is water; nitrogen and hydrogen combine also in one proportion, and ammonia is the result.

[‡] If we melt together equal quantities of tin and iron, two malleable and ductile metals, the compound produced will have totally lost the properties which its constituent parts possessed before their union; for the alloy formed will be a very brittle metal. If liquid ammonia and muriatic acid, both fluids of a strong odour, be mixed in proper proportions, a fluid will be produced entirely devoid of smell; viz. muriate of ammonia.

If nitrate of ammonia and sulphate of soda, both in crystals, *What is simple affinity?*

When two substances unite merely in consequence of their mutual attraction, they are said to combine by virtue of simple affinity §.

What is compound affinity?

The action of two compound substances, whereby they mutually decompose each other, and produce two or more new compounds ||.

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be rubbed together in a stone mortar in equal proportions, the mixture will be converted to a fluid.

§ The following experiments will serve to exemplify some cases of simple affinity:—Take a portion of acetate of soda, pour muriatic acid upon it in a retort, and distil it to dryness. The acetic acid will be expelled, and the muriatic acid will be found in combination with the soda, united so strongly that the most intense heat will not be able to separate it. This effect is owing to the soda having a greater affinity for muriatic acid than it has for the acetic. If a portion of nitric acid be now added to the muriate of soda, and heat applied, the muriatic acid will be again disengaged, and the nitric acid will be in possession of the soda. Lastly, If to the nitrate of soda, sulphuric acid be added, and these exposed to a due degree of heat, the nitric acid will be expelled, and the sulphuric acid will be in possession of the alkali, forming a true sulphate of soda. These changes all take place in consequence of chemical affinity. By this affinity acetic acid combines with soda, and forms a salt called acetate of soda; but muriatic, nitric, and sulphuric acid, have each of them a stronger affinity for soda, and their respective affinities are in the order in which they have been named.

|| If into a solution of sulphate of ammonia there be poured nitric acid, no decomposition is produced, because the sul-

What do you mean by disposing affinity?

When bodies, which apparently have no tendency to unite of themselves, combine in consequence of the addition of another substance; the union is said to be produced by means of *disposing* affinity.

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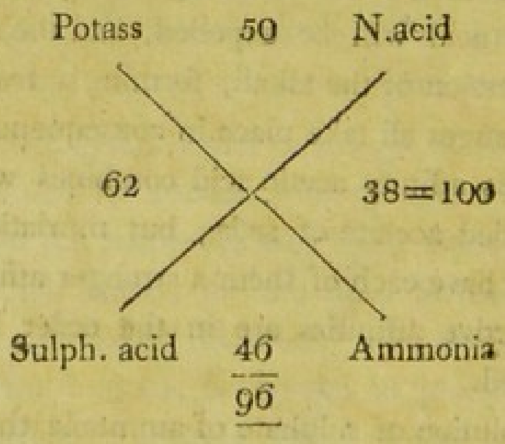
phuric acid has a stronger affinity than nitric acid for ammonia. But if a solution of nitrate of potass be poured in, we obtain by evaporation two new bodies, *sulphate of potass,* and *nitrate of ammonia.* In this case, the sulphuric acid of the sulphate of ammonia attracts the potass of the nitrate of potass, at the same time that the ammonia attracts the nitric acid; and to the agency of these united affinities the double decomposition must be attributed. The manner in which these combinations take place has been explained by the following diagram—the idea of which first occurred to Dr. Cullen. In order to understand it, let the affinity of potass to sulphuric acid be = 62; that of nitric acid to ammonia = 38; that between nitric acid and potass = 50; and that of the sulphuric acid and ammonia = 46. Now, let us suppose that all these forces are placed so as to draw the ends of two cylinders crossing one another, and fixed in the middle in this manner.



It is evident, that as 62 and 38 = 100 are greater than

What other terms are employed on the subject of chemical affinities?

There are what are called *quiescent* attractions, and *divellent* attractions.

What do you mean by quiescent attractions?

When two or more bodies are presented to each other, the attractions which tend to preserve their original arrangement of parts are denominated the *quiescent* affinities*.

$50 + 46 = 96$, they would overcome the other forces, and shut the cylinders.

In like manner acetate of alumine, which is used by the dyers and calico-printers, cannot be formed by the direct mixture of its component parts; for acetic acid exerts no action upon alumine, however its parts may be divided by mechanical means. But if we mix sulphate of alumine with acetate of lead, a mutual decomposition will take place, and the article required will be produced.

If *concentrated* nitric acid be poured upon iron, no union will take place. The component parts of the nitric acid have so great an affinity for each other that the iron has no power to effect a decomposition. But if a few drops of water be added, the union between the oxygen and nitrogen of the nitric acid will be weakened, part of its oxygen will combine with the iron, a violent action will take place, clouds of nitrous gas will be disengaged in abundance, and the iron will soon be entirely dissolved in the acid.

* If a solution of nitrate of silver be poured into a solution of muriate of soda, two new substances will be formed; viz., nitrate of soda, and muriate of silver; the latter of which, being insoluble in water, will be precipitated. In this experiment the affinity of the nitric acid to the silver, and the mu-

What is meant by divellent affinities?

Those attractions which tend to destroy the original compound, and to form new arrangements, are called the *divellent* affinities.

What advantage do we derive from the study of chemical affinities?

From all that has hitherto been explained, this seems to be beyond doubt the most important part of chemistry; for it is only from a thorough knowledge of the affinities, which different substances have for each other, that we shall ever attain a complete analysis of the productions of nature.

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riatic acid to the soda, are the *quiescent* affinities; whereas the affinity of the nitric acid to the soda, and the muriatic acid to the silver, are the *divellent* affinities. Hence no new arrangement of parts in any mixture can take place, unless divellent attraction exist.

Among the affinities of any substance, there is generally at least one peculiar to that substance which stamps it as one of its generic characters; and it is of the utmost importance to the student, in the most early stage of his progress, to imprint these characteristics upon his mind as often as he happens to meet with them. It is these predominating affinities which are more particularly serviceable in the classification of the chemical properties of different substances, and of the chemical phænomena derived from them. Thus, affinity for oxygen distinguishes inflammable substances; and the reciprocal affinity of acids and alkalies constitutes acidity and alkalinity. Thus, barytes has a superior affinity for sulphuric acid, and lime for the oxalic acid, &c.

How should a pupil proceed to acquire what seems so essential to chemistry—a knowledge of these affinities?

He must practise as well as study the various tables of affinities of Bergman, Pearson, and others. The original tables were compiled by Geoffroy, near a century ago.

How are chemical affinities noted in these tables?*

The name of the substance, whose affinities are

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* The following single example may serve as a specimen of the tables of affinities, and will be sufficient to explain the nature of all others. Let the question be Sulphuric Acid, and it will be formed thus :—

SULPHURIC ACID.

Barytes.
Strontian.
Potass.
Soda.
Lime.
Magnesia.
Ammonia.
Alumine.
Metallic oxides.
Water.

This table is designed to show that barytes has the strongest affinity for sulphuric acid, and will detach it from any of the required, is always placed at the head of the column, and separated generally by a line; below this the other bodies are placed in the order of their attraction to the first substance:—thus in respect to the affinities peculiar to *sulphuric acid*, it appears that barytes, which is the nearest, would separate strontian, potass, or any one of the succeeding substances, from sulphuric acid, which prefers barytes to all other bodies whatever.

Are these tables to be depended upon in every case of chemical composition and decomposition?

These tables, notwithstanding some exceptions*, are so extremely useful that the study of them cannot be too strongly inculcated; for in most cases they may be safely trusted by the practical chemist.

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succeeding substances in the list; actual experiment will confirm it.

* The affinities of bodies are affected by the proportions in which they are presented to each other, by the cohesion of their parts, by chemical repulsion, &c. Berthollet has shown that substances are capable of decomposing each other reciprocally, if they be added respectively in the proper quantity. Thus sulphuric acid decomposes nitrate of potass altogether, by the assistance of heat. The nitric acid is driven off, and there remains behind sulphate of potass. But if nitric acid be poured into sulphate of potass in sufficient quantity, it takes a part of the base from the sulphuric acid, and nitrate of potass is regenerated. In like manner phosphoric acid decomposes muriate of lead, and muriatic acid decomposes phosphate of lead.

What is repulsion?

Repulsion is a peculiar property, inherent in the particles of all matter, which gives them a constant tendency to recede from each other†.

How does this property of matter operate?

It operates both at sensible and at insensible distances.

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† Sir Isaac Newton found that when a convex lens was put upon a flat glass, it remained at the distance of the $\frac{1}{137}$th part of an inch; that a very considerable pressure was required to diminish this distance, and that no force which can be applied will bring them into actual mathematical contact. Other philosophers have shown that the particles of no body whatever are in such contact; that in every case there is a distance between them; consequently that the particles of all bodies *repel* each other. According to Boscovich, the atoms, of which all bodies are composed, are mere mathematical points, destitute of extension and magnitude, but capable of acting on each other with a force which differs in intensity, and in kind, according to the distance. At sensible distances the force is *attractive*, and diminishes inversely as the squares of the distance. At the smallest distances the force is *repulsive*; it increases as the distance diminishes, and at last becomes infinite, or insuperable; so that absolute contact, of course, is impossible. Dr. Thomson, vol. iii. 272. The particles of all gases and of atmospheric air evidently repel each other. It is to repulsion that they are indebted for their elasticity.

Some bodies have such a repulsion for water that it is difficult to wet them. The spec. gravity of steel is much greater than that of water, yet if a dry steel needle be placed with care upon the surface of a bason of water, the repulsion of the water will

What instances are there of the former kind of repulsion?

The only kinds of repulsion that can be exhibited to the senses, are those of electricity* and magnetism†; but it is *insensible* repulsion with which chemists are more particularly concerned.

What instances have you of this latter kind, or of insensible repulsion?

The chief example that we are acquainted

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prevent its sinking. Thus, some insects will walk upon water without any of it adhering to them;

> "Or bathe unwet their oily forms, and dwell
> With feet repulsive on the dimpling well."

* If two cork balls be suspended from an insulated body with fine threads so as to touch each other, and we charge that body with electricity, the cork balls will separate immediately. The balls of course *repel* each other.

† When we present the north pole of a magnet A to the same pole of another magnet B, suspended on a pivot, and at liberty to move, the magnet B recedes as the other approaches; and by following it with A at a proper distance, it may be made to turn round on its pivot with considerable velocity. There is then a *repulsion* between the two magnets—a repulsion which increases with the power of the magnets; and this power has been made so great, by a proper combination of magnets, that all the force of a strong man is insufficient to make the two north poles touch each other.

The natural magnet is a ponderous iron-stone, of a blackish colour. It is supposed to derive its magnetic powers from the position in which it lay in the earth. If one of these natural with is the repulsion of the particles of caloric [‡] amongst themselves; which repulsion would constantly tend to infinite separation, were it not for a chemical union, which, by an irrevocable law of nature, they form with the first surrounding body: for by that law, it seems, the particles of caloric cannot exist in an isolated state.

How does this repulsive force operate upon other bodies?

It diminishes the cohesion of the integrant particles of all heated bodies, in consequence of the particles of caloric repelling each other; so

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magnets be broken in pieces, each piece will have an attracting and a repelling pole, and the middle between the poles will neither attract nor repel. The queen of Portugal was in possession of one of these natural loadstones of a very large size, and capable of sustaining a weight of more than 200 pounds. It was a present from the emperor of China, to John V. king of Portugal. If a steel needle be rubbed on one of these minerals as directed, page 471, it immediately acquires polarity:

> "The obedient steel with living instinct moves,
> And veers for ever to the pole it loves."

[‡] It is now generally imagined that what is called insensible repulsion is owing to the presence of caloric. It is well known that the elasticity of air and all other gaseous bodies is increased by heat; that is, that the repulsion between the particles of air, the distance remaining the same, increases with the temperature, so that at last it becomes so great as to overcome every obstacle which can be opposed to it. This subject is fully treated by Dr. Thomson, vol. iii. 279, to which I refer the reader.

that chemical unions, as well as chemical decompositions, are wonderfully facilitated by this species of repulsion*.

Endeavour to explain this action of caloric with more precision?

As chemical affinity takes place only between the ultimate molecules of bodies, while the attraction of cohesion remains superior to that of affinity, no other union can take place; but whenever caloric has sufficiently diminished this attraction in any substance, the particles are then at liberty to form new combinations, by their union with the particles of other bodies†.

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* It is evident, that whatever diminishes the cohesion which exists between the particles of any body, must tend to facilitate their chemical union with the particles of other bodies. One reason why some bodies require a high temperature to cause them to combine, is, that at a low temperature the attraction of cohesion is in them superior to that of affinity; accordingly it becomes necessary to weaken that attraction by caloric, till it becomes inferior to that of affinity. In like manner bodies combine more easily when held in solution by water, or when they have previously been reduced to a fine powder, as these operations diminish the cohesion which exists among the primitive or integrant particles. Sulphuric acid has no action upon a lump of fluate of lime; but if that earthy salt be reduced to powder, a violent action will ensue on the addition of the sulphuric acid, and the fluate of lime will be decomposed.

† The formation of the red oxide of mercury will exemplify the above chemical axiom. If mercury be submitted to a hea

Is the addition of caloric always necessary to promote chemical affinity?

In order that the attraction of composition may take place between two bodies, it is generally necessary either that one of the substances should be in a state of fluidity[‡], or that heat should be applied; so that caloric acts an important part, either sensibly or insensibly, in all cases of chemical affinity.

Does chemical affinity operate in consequence of the universal law of attraction?

We have reason to believe that every new com-

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little superior to that of boiling water, no new combination will be formed, but the metal will remain unaltered. If the heat be increased to 600°, or thereabouts, the attraction of cohesion of the mercury will be broken; its particles will unite with the oxygen of the surrounding atmosphere; and a new substance, *red oxide of mercury*, will be produced. If this new substance be again submitted to the operation of caloric, and the heat be raised to 1000°, the combination will again be broken, and new affinities will take place. The affinity of oxygen for caloric will now be greater than that of oxygen for mercury; the oxygen will quit the mercury, unite with the caloric, and be expelled as oxygen gas; thus the mercury will consequently once more appear in its metallic state.

Red lead is formed by long exposure of metallic lead to atmospheric air in a high temperature; but by a great increase of temperature, it is made to give out its oxygen in sufficient abundance to be collected in appropriate receivers in the form of oxygen gas; and the metal is partially revived.

[‡] This is so generally the case that a chemical adage has been founded upon it, *Corpora non agunt nisi sint soluta.*

pound is produced by virtue of the attraction to which all matter is subject, and which is equally operative on the most minute atom, as on a planetary system*.

How do you imagine that the same force which operates upon the ultimate particles of bodies, so as to produce composition and decomposition, can be sufficient to preserve the planets in their orbits†?

"We can neither comprehend the one nor the other; nor can we see why the Almighty might not as easily bestow upon one species of matter the power of acting upon another when at a distance‡, as the power of being acted upon

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[*] The attraction of the particles of bodies for each other is exemplified by small quantities of water, or other fluids, which when dropped upon a flat surface, form themselves into spherical masses.

> "That very law which moulds a tear,
> And bids it trickle from its source,
> That law preserves the earth a sphere,
> And guides the planets in their course." ROGERS.

[†] A passage of bishop Watson's will perhaps furnish as good a reply to this question as can be given. "We feel the interference of the Deity every where, but we cannot apprehend the *nature* of his agency any where. A blade of grass cannot spring up, a drop of rain cannot fall, a ray of light cannot be emitted from the sun, nor a particle of salt be united, with a never failing symmetry to its fellow, without him; every secondary cause we discover, is but a new proof of the necessity we are under of ultimately recurring to him as the one primary cause of every thing."

[‡] Dr. Herschel has shown, that not only the planets in our

and changed by matter when in actual contact§."

Is the consideration of this universal property of matter calculated to produce any peculiar reflections?

The contemplation of this subject has a natural tendency to promote the most profound feelings of awe and admiration; for the understanding

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system are preserved in their orbits by mutual attraction, but that in the sideral systems the double stars are so situated with respect to each other, that *they* must be subjected to mutual gravitation, and that they can only preserve their relative distances by a periodical revolution round a common centre. What he calls the *insulated* stars he imagines to be nearly out of the reach of mutual gravitation. He considers our sun and all the brightest stars to be of this class. They are at such immense distances, that he calculates that Sirius (the nearest of the fixt stars to us) and the Sun, if left alone, would be 33 millions of years in falling together. The same philosopher has said, that though light travels at the astonishing velocity of 200,000 miles in a second, some of the nebulæ are so far from us that the rays of light must have been nearly two millions of years in passing from them to our system. According to a writer in the thirty-second volume of the Monthly Review, N. S. 523, astronomers are now acquainted with no less than 2120 of these nebulous stars. Probably they are so many distinct worlds, appropriated by the Author of nature for the reception of intelligent beings, and for the abodes of rectitude and felicity,

> " Lightnings and storms His mighty word obey,
> And planets roll where He has mark'd their way."

§ Thomson's Chemistry, second edition, vol. iii. 176.

of the highest intelligences sinks into nothing, when compared with the energy of that Omnipotent Being, who had wisdom to contrive, and ability to endue the matter which he had formed, with the astonishing Power of operating upon its fellow matter either in contact, or when separated by the infinity of space. Well might a writer of antiquity assert, that "God saw every thing that he had made, and behold it was very good*."

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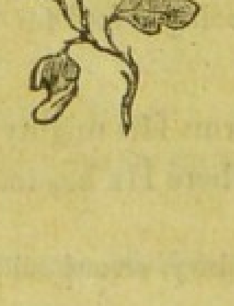
* Having now completed my original design, of furnishing the YOUNG with an elementary treatise on chemistry, it may be necessary to apologize to some readers for the introduction of those moral reflections which so frequently occur. This cannot be done better than in the language of a late popular writer:—"Every man," says he, "has a particular train of thought into which his mind falls, when at leisure, from the impressions and ideas that occasionally excite it; and if one train of thinking be more desirable than another, it is surely that which regards the phænomena of nature with a constant reference to a supreme intelligent Author." PALEY.



ADDITIONAL NOTES.

I.

Of Specific Gravity.

THE common method of taking the specific gravity of the metals, or of any solid body, is by comparing the difference which there is in their weight when weighed in air and in water; that is, to divide the *absolute* weight by the *loss*, and the quotient is the specific gravity. Thus, if a mineral which weighs three ounces in air, weighs only two ounces when weighed in water, the specific gravity of such mineral is 3; that is, if water, as it generally is, be called 1.000, the substance now examined is 3.000; or, to make it plain to the young student, if a pint of water weigh *one* pound, the same *bulk* of the mineral will weigh three pounds. See page 41.

A more ready way to determine the specific gravity of solids is to fill a phial with water, and note the weight of the whole accurately in grains. Then weigh 100 grains of the mineral or other substance to be examined, and drop it gradually into the phial of water. The difference of weight of the bottle with its contents now, and when it was filled with water only, will give the specific gravity of the matter under examination. For example, if the bottle weighs 50 grains more than it did when it was filled with water only, it shows that 100 grains of the mineral displace only 50 grains of water, and consequently that it is twice the specific gravity of water. This method is said to have been discovered by Archimedes. See Note, page 36.

The specific gravity of fluids is generally determined by an areometer, which is a graduated glass tube with a bulb, so contrived that it may swim in the fluid in a perpendicular position. The specific gravity is shown by the degree to which this instrument sinks in the fluid to be examined, and this will consequently always be lower in proportion as the liquid is lighter

The specific gravity of ardent spirits is generally ascertained by means of an hydrometer, of which various kinds are sold by the mathematical instrument makers

The following method, which was contrived by Dr. Lewis, the celebrated author of the Commercium Philosophico-Technicum, and which was communicated to me by the amiable Samuel Moore, esq. late secretary to the Society for the promotion of arts, manufactures, and commerce, I prefer to every other.

In this method the specific gravity of a liquor is estimated from the excess of the weight of a certain measure of it above that of an equal measure of distilled water. A set of weights is made for this purpose, called *carats*, or *cadukes*, in the following manner

A convenient bottle being procured, the tare of the bottle is first taken; it is then completely filled with distilled water; the weight of the water is accurately divided into two equal parts, and a weight made equal to one of these parts is marked 64; by continuing the division, are obtained the weights 32, 16, 8, 4, 2, 1 carats; so that a carat is the 128th part of the weight of the water. Another weight is then made which counterpoises the bottle when filled with water; and so many carats as the bottle filled with an alkaline lye, or any other liquor, weighs more than this waterpoise, so many carats strong is the liquor said to be.

A table of these carats, with their corresponding degrees of specific gravity, which I drew up for my own use, will be found with the other tables at the end of this volume; but in taking the specific gravity of bodies an attention should always be paid to their temperature, as the specific gravity of a body when expanded by caloric will always be less than it is when at a low temperature.

II.

Of a curious Property of Charcoal.

A property of which charcoal is very eminently possessed, and which may be regarded as a singular one, is that of absorbing, even when cold, aëriform fluids, and condensing them in its pores, in quantity exceeding many times its own bulk. A very interesting application may be made of this property. The gases which are absorded, suffering so great a condensation, two gases introduced at once into the pores of the charcoal may perhaps be made to combine. It appears from the 32d vol. of the Annales de Chimie, that water has actually been formed by this means. The subject deserves to be prosecuted;

and if strong mechanical pressure were applied at the same time, it is probable such combinations might be diversified, and carried to a greater extent. **Murray.**

III.

Of Ebullition.

Under an exhausted receiver, water will boil at the heat of 92° of Fahrenheit's thermometer; whereas under the usual pressure of the atmosphere it does not boil till it is heated to 212°; though, as the atmosphere varies in density, it occasions some little variation in this respect; for sir George Shuckburgh found by experiment, that when the barometer was at 26 inches, water boiled at less than 205 degrees, but when it was at 31 inches it required to be heated to near 214° before it would boil.

Under the common pressure of the atmosphere

Ether boils at	98°
Alcohol	176
Water	212
Nitric acid	248
Sulphuric acid	546
Phosphorus	554
Mercury and Linseed oil	600

Dr. Black made experiments upon several liquids in vacuo, and found that in general they all boiled with about 140 degrees of heat less than when bearing the weight of the atmosphere. Vitriolic ether (if the pressure of the atmosphere be removed) will boil when 52 degrees below the cold sufficient for freezing water. See pages 60 and 121.

IV.

Of the Combinations of Caloric.

Mr. Murray has remarked, "We see no cause why, for a great extent of the thermometrical scale, bodies should receive caloric without entering with it into any intimate combination; why, when the temperature is raised to a certain point in each body, this combination should suddenly take place; and why, after another interval in the thermometrical scale, it should be renewed;—for example, why water at 32°, and, under the common atmospheric pressure, at 212°, and at those points *only*, should contract an intimate union with caloric." It is true, the *cause* which produces these effects is concealed from our investigation, but surely many important results, from these seeming anomalies of nature, must present themselves to every contemplative mind, affording it fresh assurances that nothing but beneficence united with consummate wisdom could have dictated such curious and efficacious deviations in the established laws of the universe.

> "'Twas this that guided thy Almighty hand,
> When formless chaos heard thy high command;
> When pleased, thy eye the matchless work reviewed,
> And goodness placid, spoke 'that all was good.'"

V.

Of Water.

In addition to what has been said in the note to chap. iii. p. 118, on the peculiar law which water observes during its change of temperature; it is worthy of notice that as rivers, lakes, &c. give out caloric to the currents of cold air passing over them, the upper stratum of water becomes of greater specific gravity, and therefore sinks, and that this occasions the rise of a portion of warmer water which gives out its caloric in like manner; and that this constant circulation very much contributes to moderate the rigour of winter throughout the regions within what are called the temperate zones. In the ocean and other deep bodies of water this circulation goes on for a considerable time, and an immense quantity of caloric is thus thrown into the atmosphere—but if no limit had been put to this process, what would have become of those innumerable tribes of creatures that inhabit this element. The exigency has however been admirably provided for by the Author of Nature; for whenever the whole mass of water arrives at the temperature of 42°—5, its specific gravity no longer increases by the further diminution of its temperature, and the circulation that we have been speaking of entirely ceases. How completely does this simple deviation from a general law answer all the purposes for which it was intended!

> "Such the all-perfect hand
> That pois'd, impels and rules the steady whole."

On the top of a hill near Lochness in Scotland, whose perpendicular height is nearly two miles, there is a small lake of fresh water, hitherto said to be unfathomable, which never freezes during the coldest winters. Here the depth is so great that the circulation is not completed before the return of summer; whereas the Lochaawyn, or Green lake, 17 miles distant, is perpetually covered with ice.

VI.

Of Oxygen Gas.

Details of several surprising cures by means of oxygen gas have been given in the different volumes of Mr. Tilloch's Philosophical Magazine[*]. By the new invented gasometers, and the apparatus sold with them, any kind of factitious air may be accurately measured, and mixed with any portion of atmospheric air that the physician may prescribe. See page 73. And notwithstanding the ridiculous effects which have been attributed to pneumatic medicine, by the over sanguine practitioner, or by the designing impostor, there can be no doubt but that the addition of more oxygen gas to atmospheric air, when aided by proper tonics, has in many instances been very efficacious, and peculiarly so in those female complaints which arise from want of sufficient tone and vigour in the system.

Thus the afflicted, feeble, sickly maid
Whose spirits languish, and whose health declines,
Looks to pneumatic chemistry for aid,
And on that science every hope reclines.

Anxious she marks the mixture of the airs,
And joys to hear them bubble and expand[†];
While fell Hysteric every sinew tears,
And overwhelms her with his leaden hand.

Trembling she grasps the cold metallic tube,
In fear mysterious, and with caution drinks;
While every pulse acquires a kinder throb,
And still increases as the column[‡] sinks,

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[*] See also an interesting "Essay on the Medicinal Properties of Factitious Airs," by Tiberius Cavallo, esq. 8vo. Dilly, 1798.

[†] When the oxygen gas is prepared, it is thrown up through water into the gasometer in bubbles, where it expands and mixes with the atmospheric air, previously measured into it.

[‡] The gasometer is covered by an inverted cylindrical vessel which preserves the air from escaping; this is hung upon pulleys, and sinks lower and lower in the water, as the gas is inhaled from underneath it.

The heaving lungs inhale the vital gas,
The blood absorbs it as it ebbs and flows;
It gives fresh colour to the fluid mass,
And the whole frame with pristine vigour glows.

Returning health adorns the roseate cheek,
And decks the features with its every charm;
While new designs, new energies bespeak,
And Beauty's self resumes her native form.

With emulation now her bosom burns;
The grateful female cultivates her mind,
And feels the sweetest pleasure while she learns
The science[*] sent by Heaven to bless mankind.

VII.

Of the Production of Oxygen Gas.

Oxygen gas may be procured in any quantity from the black oxide of manganese, which is a cheap article. It is only necessary to pulverize the manganese and expose it in an iron retort to a proper degree of heat. The gas, which will rise in great plenty from the retort, may be received in bladders or any appropriate vessels. Dr Priestley, who discovered this air called it dephlogisticated air. According to Mr. Parkinson, one pound of manganese will furnish ten gallons of this gas. It may be procured however with more ease, and in greater purity, from the oxygenized muriate of potash than from any other substance; but as this is a dear article, manganese will be chosen for all common purposes. See page 74.

VIII.

Of the Effect of Oxygen upon the Blood.

To prove that oxygen gas is really imbibed by the blood in the lungs, Dr. Goodwin opened the chest of a living dog, and exposed the lungs and heart to view. It was a striking spectacle to observe the *black* blood, in its return from the lungs, and in its passage to the heart, change to a bright *vermilion* colour. As the dog became exhausted, it was found necessary to inflate the lungs by artificial means. When this was omitted, the blood received by the heart was black, and in a little time its action ceased. But when the lungs were again made to col-

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[*] Chemical science is here intended.

lapse and distend, by the inflation of common air, the blood in the pulmonary vessels regained its former crimson colour, and the action of the heart and arteries was excited anew. See page 78.

IX.

Of the Circulation of the Blood.

According to Dr. Thomson, one principal use of the blood is to furnish fibrina to supply the waste of the muscles; for as neither the chyle nor the lymph contains fibrina when they flow into the blood, there must be a continual decomposition of chyle and lymph in the blood-vessels, in order to form this substance. We know that carbon and hydrogen are thrown out by the act of respiration; he therefore concludes that one use of the air absorbed is to abstract a quantity of carbon and hydrogen from the chyle, by compound affinity, in such proportions that the remainder becomes fibrina*. For the information of young readers, the following account of the apparatus for elaborating the blood is copied from Paley's Natural Theology:

"There is provided in the central part of the body a hollow muscle, invested with spiral tubes, running in both directions. By the contraction of these fibres, the sides of the muscular cavities are necessarily squeezed together, so as to force out from them any fluid which they may at that time contain: by the relaxation of the same fibres, the cavities are in their turn dilated; and, of course, prepared to admit every fluid which may be poured into them. Into these cavities are inserted the great trunks, both of the arteries which carry out the blood, and of the veins which bring it back. This is a general account of the apparatus: and the simplest idea of its action is, that, by each contraction, a portion of blood is forced as by a syringe into the arteries; and, at each dilation, an equal portion is received from the veins. This produces at each pulse, a motion and change in the mass of blood, to the amount of what the cavity contains, which in a full-grown human heart is about an ounce, or two table-spoons full. Each ventricle will at least contain one ounce of blood. The heart contracts four thousand times in one hour; from which it follows, that there passes through the heart every hour four thousand ounces, or 350 lbs. of blood. Now the whole mass of blood is about 25 pounds; so that a quantity of blood equal to the whole blood within the body passes through the heart fourteen times in one

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* System of Chemistry, vol. iv. 725.

hour; which is about once every four minutes. Only consider what this is in very large animals. The *aorta* of a whale is larger in the bore than the main pipe of the water-works at London bridge; and the water roaring in its passage through that pipe is inferior in impetus and velocity to the blood gushing from the whale's heart." According to Dr. Hunter, ten or fifteen gallons of blood are thrown out of the heart of a whale at a stroke, with an immense velocity, through a tube of a foot diameter. The whole idea fills the mind with wonder. See Dr. Hunter's account of the dissection of a whale, in the Philosophical Transactions.

"It was necessary that the blood should be successively brought in contact or proximity with the air: therefore, as soon as the blood is received by the heart from the veins of the body, and before that it is sent out again into its arteries, it is carried by the force of the contraction of the heart, and by means of a supplementary artery, to the lungs; from which, after it has undergone the proper change, it is brought back by a large vein once more to the heart, in order, when thus prepared, to be from thence distributed anew into the system. See page 79.

"An anatomist, who understood the structure of the heart, might say beforehand that it would play: but he would expect, I think, from the complexity of its mechanism, and the delicacy of many of its parts, that it should always be liable to derangement; or that it would soon work itself out. Yet shall this wonderful machine go, night and day, for eighty years together, at the rate of a hundred thousand strokes every twenty-four hours, having, at every stroke, a great resistance to overcome; and shall continue this action for this length of time without disorder, and without weariness."

X.

Of the Renovation of the Atmosphere.

It has been imagined that the atmosphere is occasionally renovated from other sources than those mentioned page 84. Dr. Darwin, in his dissertation on the winds, concludes that immense masses of air are set at liberty from their combinations with solid bodies, within the polar circle, or in some region to the north of us; and that they thus perpetually increase the quantity of the atmosphere; and that this is again at certain times re-absorbed, or enters into new combinations at the line or tropical regions: by which means the atmosphere is perpetually renewed, and rendered fit for the support of animal and vegetable life. Botanic Garden, page 84.

The following idea is merely hypothetical, but it deserves perhaps some notice.—" The *moisture* contained or dissolved in the ascending heated air at the line, must exist in great *tenuity*, and by being exposed to the great light of the sun in that climate, the water may be decomposed, and the new airs spread on the atmosphere from the line to the poles." Ibid. page 86.

> " On liquid air HE bade the columns rise,
> That prop the starry concave of the skies;
> Diffus'd the blue expanse from pole to pole,
> And spread circumfluent ether round the whole."
>
> BLACKLOCK.

The action of the sea also has probably considerable influence in purifying the atmosphere. See page 84.

XI.

Examples of Affinity.

Take a little common magnesia, and pour by degrees diluted nitrous acid upon it till the whole of the earth be dissolved. This is an instance of simple chemical affinity. But if a solution of potass be poured upon the former mixture, the potass having a greater affinity for the acid will take it from the magnesia, and the magnesia will again be precipitated.

To a solution of soap add a little weak sulphuric acid. The acid having a stronger affinity for the alkali of the soap than the alkali has for the tallow, the acid will unite with the alkali, and the separated tallow will be seen to float upon the surface of the liquor.

Dissolve a few ounces of sulphate of iron in water, by adding the salt by degrees till the liquor becomes turbid; then if a skain of cotton thread be dipped in the solution and shaken a little in it, the thread will take up the whole of the oxide of iron, and render the liquor transparent. This effect is produced in consequence of the great affinity which cotton has for the oxides of iron.

If mercury be put into a *glass* bottle, the surface will appear convex, owing to the small affinity which mercury has with glass; but if it be put into a *metallic* vessel, the surface of the mercury will appear concave like that of other fluids, because of its tendency to combine with the sides of the vessel. This may be adduced as a striking proof of metallic elective attraction.

" The phænomena of dyeing may also be referred entirely to chemical principles. The colouring particles possess chemical properties that distinguish them from all other substances; they have attractions peculiar to themselves, by means of which they unite with acids, alkalies, metallic oxides, and earths. The difference in the attractions of the colouring particles for wool, silk, and cotton, is sometimes so great that they will not unite with one of these substances, while they combine very readily with another; thus *cotton* receives no colour in a bath which dyes *wool* scarlet." Berthollet, vol. i. page 22. Several curious and instructive instances of the effects of chemical affinity in the art of dyeing may be seen in that work, vol. i. 29, and following pages.

Chemical affinity may be pleasingly illustrated by the composition and decomposition of writing-ink. Take a little tincture of galls, and a little of the solution of green copperas, both colourless liquors, and if poured together the mixture becomes black; from the affinity which gallic acid has for the oxide of iron in the copperas. Then pour in a little weak aquafortis, and the liquor will become immediately transparent; this arises from the metal leaving the first acid to unite with the last, to which it has a greater affinity. But if a solution of potass be now added, the nitrous acid will quit the iron, and unite with the alkali; thus the iron being once more disengaged will again be caught by the gallic acid in the infusion, and once more produce a black liquor. See page 113.

Many other instances of chemical affinity will be found in the chapter of experiments.

XII.

Atmospheric Pressure.

The rise of water in a pump was formerly attributed to the horror that nature had of a vacuum. This absurd notion was refuted about the middle of the seventeenth century, by the following occurence:

The Duke of Florence, having occasion to raise water to the height of 50 or 60 feet, ordered a common pump to be made for that purpose; but when it was completed the workmen were astonished to find that it would not work.

The matter was referred to the celebrated Galileo, but he was unable to account for it in any way. All they were able to determine was, that water would not rise in a common pump more than from 32 to 35 feet. The fact remained inexplicable till philosophers caught the idea of atmospheric pressure; since when, the suspension of mercury in the barometer, and water in a pump, have been well understood. See page 58.

XIII.

Of the Formation of Water.

In 1798, Mr. Seguin made a grand experiment for the composition of water. He expended no less than 25,582 cubic inches (or nearly two hogsheads) of inflammable air, and 12,457 of vital air. The first weighed 1039 grains, and the second 6210, amounting to 7249 grains, and the water obtained amounted to 7245 grains, or about three-fourths of a wine pint. The loss was only four grains. Another experiment was afterwards made by Le Fevre, in which nearly two pounds and a quarter of water were produced *. See page 130.

XIV.

Of the Giants' Causeway.

The Giants' Causeway, in the county of Antrim in Ireland, is the most remarkable one of its kind in the world. The name of it may naturally convey to us the idea of some stupendous work of art; and as such it seems to have been considered in the days of ignorance, when the name was first applied; modern philosophy, however, looks on it with a different eye. To conceive a proper idea of this unparelleled curiosity, we may imagine an approach to it from the sea; its first appearance is that of a bold rocky shore, with extensive ranges of shelving, calculated for an immense promenade. These rocks, however, instead of being disposed in laminæ, or strata, form basaltes, or angular columns, so closely attached to each other, that, though perfectly distinct from top to bottom, scarcely any thing can be introduced between them. Some account of this stupendous object of curiosity has already been given at page 287, but as the whole is still more curious in its minute parts than in the great, the following additional particulars will perhaps not be thought uninteresting.

The columns themselves are not each of one solid stone in an upright position, but composed of several short lengths exactly joined, not by flat surfaces, as in works of art, but, what is most extraordinary, they are articulated into each other, as a bone often is into its socket, the one end of the joint having a cavity into which the convex end of the opposite is exactly

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* Dr. Black, vol. ii. page 236.

fitted; which is not visible but by disjointing the two stones. The depth of the concavity is generally from three to four inches; and what is still further remarkable, the convexity and the corresponding concavity are not conformed to the external pentagonal figure of the column, but exactly round, and as large as the size of the column will admit. It is still further remarkable, that the articulations of these joints are frequently inverted. In some the concavity is upwards, in others the reverse. A part of one of these columns was exhibited in the Leverian Museum, and is probably still in the possession of Mr. Parkinson.

The formation of this curious natural production has been accounted for by supposing that the whole body of the rock was once in a state of fluidity, being no other than the lava of a burning mountain; that the prodigious mass cracked in its cooling into the forms we now see it; that it may since in some measure have been deranged by earthquakes; that these have swallowed up the volcano itself; and that the waters of the neighbouring ocean now roll over the place where it once stood*. Those geologists, however, who have embraced the system of Werner, attribute all these effects to the agency of water. Can any thing be more gratifying to a well-informed mind, than the examination of these arcana of nature? "The sensualist may imagine that he enjoys the world; but to enjoy it truly is to be sensible of its greatness and its beauty."

> "Presented to the cultur'd eye of taste,
> No rock is barren, and no wild is waste."

XV.

Of Crystallization.

Gahn had observed, that in breaking a pyramidal crystal of carbonate of lime, it afforded rhomboidal fragments, of which it appeared to be entirely formed. Bergman from this conceived the idea, that in every crystal there exists a primitive form, from which the actual forms, having often no resemblance to it, may be generated by the superposition of decreasing laminæ; and that, by the mechanical division of crystals, this form may be detected, and the laws by which it gives rise to the different crystals determined. This is the basis of the system of Haüy. He demonstrated what Bergman had scarcely more than imagined. He succeeded in showing that in every crystallized substance, whatever may be the dif-

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* Walker's Geography.

ference of figure which may arise from modifying circumstances, there is, in all its crystals, a *primitive* form, the nucleus as it were of the crystal, invariable in each substance, giving rise to the actually existing outward forms.

It is well known to those who work on gems, that crystals can be mechanically divided only in certain divisions, so as to afford smooth surfaces, and that if separated in any other way, the fracture, instead of being polished like the others, is rugged and uneven. Ample extracts from the work of the Abbé Haüy will be found in the first vol. of the Philosophical Magazine. See also Murray's System of Chemistry, vol. i. 48.

XVI.

Of Combustion.

In addition to what has been said, chap. 12, of the effects of combustion, it may be remarked that animal and vegetable substances are converted into water and carbonic acid during this process, by the union of their hydrogen and carbon with the oxygen of the atmosphere; and that, in time, the same water and the same carbonic acid are absorbed by vegetables, and again decomposed in order to set the oxygen at liberty to produce fresh combustions, while the vegetating organs appropriate the hydrogen and carbon to promote their growth and nourishment. A regular circle of compositions and decompositions is thus perpetually going on, and all organized beings are made to surrender in due time, to the general mass, those elementary substances which nature kindly lent them for the preservation of their existence. See page 131. Is not this admirable simplicity of nature a conclusive proof of the infinite wisdom of the Deity, and that the greatest possible sum of beauty and of happiness was his ultimate object!

"The whole and every part proclaims
His infinite good-will;
It shines in stars, and flows in streams,
And bursts from every hill.

We view it o'er the spreading plain,
And heav'ns which spread more wide;
It drops in gentle show'rs of rain,
And rolls in ev'ry tide."

BROWNE.

XVII.

Of the Effects of Intense Cold.

In Iceland and Germany the thermometer frequently falls to zero, which is 32 degrees below the freezing point. At Hudson's Bay it has been known to sink even 50 degrees lower. When stones or metals which have been exposed to such degrees of cold are touched by the tongue, or the softer parts of the human body, they absorb the heat from those parts with such rapidity that the flesh becomes instantly frozen and mortified, and the principle of life in them is extinguished. Some French academicians who made a journey to the northern end of the Baltic, and wintered under the polar circle, found it necessary to use all possible precautions to secure themselves from the dreadful cold which prevailed. They prevented as much as possible the entrance of the external air into their apartments; and if at any time they had occasion to open a window or a door, the humidity of their breath, confined in the air of the house, was condensed and frozen into a shower of snow; their lungs, when they ventured to breathe the cold air, felt as if they were torn asunder; and they often heard the rending of the timber around them by the expansive power of the frost on the fluid in its pores. In this terrible cold the thermometer fell to 33° *below* zero*. The most intense cold ever known in the neighbourhood of London was on December 25, 1796, when the thermometer indicated 2° below zero. See page 136.

XVIII.

Of the Recession of the Ocean.

At the summit of Mount Perdu, in the Pyrenees, which is nine thousand feet above the level of the sea, a prodigious number of marine productions are found, which seem to indicate that there has been either a great recession of the ocean, or a vast elevation of the mountainous parts of the earth. The former is perhaps the most probable supposition. What then has become of this immense body of water? Some have supposed that it has risen into the atmosphere, and remains suspended there; some, that it has found a place in the heart of the globe; and there are others who even imagine that it has

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* Dr. Black's Lectures, vol. i. 69.

passed off to other planets. But since it is known that water is a compound decomposable substance, other solutions of this difficult question might be given. Water enters into the composition of most substances; and if it unite to some without losing its nature, it cannot combine with others unless it be decomposed, and cease to be water. It is thus that it abandons its oxygen to metals, and its hydrogen to plants. These two principles once separated, cannot unite again to form water, but by a concurrence of circumstances which does not often take place. M. Poiret, who has written upon this subject, in the sixtieth volume of the Journ. de Phys. seems to be of opinion, that when the earth was nearly covered with water, a considerable portion of this fluid would necessarily be consumed by marine animals, which would of course be more numerous as the mass of waters was greater. This supposition is strengthened by our knowledge of one circumstance, that hydrogen is the base of animal fat, and that in no animal is fat so abundant as in various species of fish, especially in the cetaceous tribe, of whose substance it often constitutes the principal part. Besides, there existed vast numbers of shell fish, and of polypi, which latter employ themselves in constructing calcareous rocks, that are uniformly composed of the pulverized remains of their shells and their tubes joined together; which, insensibly raising themselves from the sea, have reached the surface of the water. These rocks at first were mere barren islands, but soon afterwards became covered with an abundant vegetation. This great work was thus effected at the expense of the waters, which diminished more rapidly as organized beings became more numerous. He goes on to state, that a vast consumption of water has been occasioned by volcanos, and by the formation of stony bodies; some of which, particularly the calcareous, frequently contain one-fourth of their mass of water. The last cause of the consumption of the water which he mentions, is the vegetation of plants. By this process water is plentifully and perpetually decomposed, and more and more so in proportion as the surface of the earth increased. Hales found that a plant which weighed three pounds, acquired an augmentation of two pounds after remaining for some time with its roots in water. If to this fact we add the idea of a vegetation existing for thousands of ages, and of those immense forests which once covered the countries now cultivated; and lastly, the extensive depths of peat, and the thick beds of coal, that are so many vegetable remains, what an idea must we have of the enormous quantity of water necessary for the formation of all these substances, and for the support of such an abundant vegetation for such a period of time! See page 138.

A late discovery made by Mr. Harrop, and which I have noticed in page 140 of this work, adds another source to those already enumerated by M. Poiret, to prove the diminution of water. This discovery announces a power in nitrogen gas to absorb oxygen from water, till the mixture of nitrogen and oxygen arrives at that proportion which constitutes atmospheric air.

> "Water restrain'd gives birth
> To grass and plants, and thickens into earth;
> Diffus'd it rises in a higher sphere,
> Dilates its drops, and softens into air:
> Those finer parts of air again aspire,
> Move into warmth, and brighten into fire;
> That fire once more, by denser air o'ercome,
> And downward forc'd, in earth's capacious womb,
> Alters its particles, is fire no more,
> But lies metallic dust, or pond'rous ore." PRIOR.

XIX.

Morveau's Preservative Phials.

The portable phial contrived by Morveau for preventing contagion may be prepared thus:

Forty-six grains of black oxide of manganese in coarse powder, are to be put into a small strong glass phial, with an accurately ground stopper, to which must be added about two drachm measures of nitric acid of 1.400 specific gravity, and an equal measure of muriatic acid of 1.134; the stopper is then to be replaced, and the whole secured by inclosing the phial in a strong wooden case, with a cap which screws down so as to keep the stopper safe. It is to be used in hospitals, or other places of infection, by simply opening the phial, with the nose averted, and replacing the stopper as soon as the smell of the oxy-muriatic gas is perceived. A phial of this kind, properly prepared, may be used several years without losing its effect. The mixture however ought not to occupy more than one third of the bottle.

XX.

Of Lime and Water Cement.

Dr. Watson has remarked, that "in countries where they have no common materials for making lime, it would be worth while for the farmer to examine the earth which may be met with on the surface of the ground, or at a little distance below it; for that calcareous substances are not always united into hard compact masses, but are sometimes found in the form of loose earth, and that of different colours."

While writing on lime, some persons may be glad to be informed how a cement may be made with common lime, that will harden under water. What is called *poor* lime has this peculiar property; but as this species of limestone rarely occurs, it is an expensive article. The following is a good substitute, and may be used for water-cisterns, aqueducts, &c.—Mix four parts of gray clay, six of the black oxide of manganese, and ninety of good limestone reduced to fine powder; then calcine the whole to expel the carbonic acid. When this mixture has been well calcined and cooled, it is to be worked into the consistence of a soft paste with sixty parts of washed sand. If a lump of this cement be thrown into water it will harden immediately. Such mortar however may be procured at a still less expense, by mixing with common quick-lime a certain quantity of what are called the *white* iron ores, especially such as are poor in iron. These ores are chiefly composed of manganese and carbonate of lime, or chalk. Lime and sand only, whatever may be the proportion of the mixure, will certainly become *soft* under water.

XXI.

Of Light.

This work being intended to teach only the first principles of natural and chemical philosophy, I purposely omit entering into a general investigation of the nature of *light*. It is a subject but imperfectly understood, and what is known is in general too abstruse for the comprehension of youth, till they have made very considerable proficiency in other branches of natural philosophy, The *velocity* of light is however so admirably calculated to impress the young mind, that I could not resist making the following extract from Dr. Thomson's System of Chemistry:—

"It has been demonstrated that light takes about eight minutes in moving across one half of the earth's orbit; consequently it moves at the astonishing rate of 200,000 miles in a second; therefore, if each of its particles weighed the thousandth part of a grain, its force would be greater than that of a bullet discharged from a musket. Were it even the millionth part of a grain in weight, it would destroy every thing against which it struck. If it even weighed the millionth part of *that*, it would still have a very sensible force. But how much less must be a particle of light, which makes no sensible impression upon so delicate an organ as the eye? We are certain then that no particle of light can weigh $\frac{1}{1\,000,000,000\,000}$th of a grain*." See page 443.

It may be remarked that light "sets out from the body of the sun with a velocity equalled only by the extent of its journey. It goes from planet to planet, from sun to sun, distributing colours, illuminating and enlivening all nature. It never travels by circuitous routes, like the other great bodies which traverse void space, but passes on in straight lines; and if it does not pass through or combine with the bodies it meets, it is reflected back on other objects. It seems to be destined for the benefit of the whole universe, and consequently travels over all."

Physical and Metaphysical Inquiries.

" 'LET THERE BE LIGHT,' the great Creator said,
His word the active child obey'd;
Awhile the Almighty wond'ring view'd,
And then himself pronounc'd it good."

YALDEN.

XXII.

Of the Nature and Formation of Nitre.

The greatest part of the nitre we have is brought from the East-Indies. See page 270. Should this supply fail, it may, after the example of the French, be formed artificially in Europe. During the second and third years of the French republic, the government required every district to send two intelligent young persons to Paris. This convocation, consisting of nearly eleven hundred individuals, received regular instruction from their first chemists partly concerning the manufacture of cannon, and partly concerning the making of salt-petre for gunpowder. This body of pupils was afterwards distributed among the different establishments in proportion to their abilities, and salt-petre was soon furnished by them in abundance. Ann. de Chim. xx. 298.

It is suspected that the French in this unexpected production of nitre availed themselves of a discovery of our countryman Dr. Milner, who formed nitrous acid by passing ammonia over oxide of manganese placed in a tube, and submitted to a red heat.

The theory of the formation of nitre was little known till

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* Thomson's Chemistry, vol. i. 279.

lately. An admirable paper on this subject, by Chaptal, occupying 47 pages, may be seen in the Annales de Chimie, tom. xx. Annexed is an useful paper on the refining of saltpetre. Also a paper by Guyton on the same subject, tom. xxiii. of the same work.

A great quantity of nitre is used by the makers of oil of vitriol. It is ground small, and mixed with sulphur in order to afford oxygen to the sulphur while burning. For the same purpose it was used by the ancients in that destructive composition of antiquity, called the *Greek-fire.* Sulphur, resin, alcohol, camphor, and other combustibles were melted with it, and in this melted mass woollen cords were dipped, which were afterwards rolled up for use. These balls being set on fire were thrown into the tents, &c. of the enemy; and as the combustibles were furnished with a constant supply of *oxygen* from the nitre, nothing could extinguish them.

When Constantinople was attacked in the reign of Leo, many of the ships of the besiegers were destroyed by this chemical composition. For many centuries the method of making this dreadful article of destruction was lost; but it has just been re-discovered by the librarian of the elector of Bavaria, who has found a very old Latin manuscript which contains directions for preparing it.

XXIII.

Of Muriate of Lead.

Muriate of lead, which is readily made, will afford the pupil a pleasing example of metallic crystallization. Take common red litharge, pour over it one-third of its weight of good strong muriatic acid, and stir it well with the litharge. When it has stood to become dry, melt it in a crucible, and pour it into a metallic vessel in a state of fusion. The cooled mass will be of a beautiful brilliant yellow, and when broken will exhibit the most regular crystallization that can be conceived. See page 287.

XXIV.

Of the Uses of Alum.

The employment of alum in the arts is very extensive. It is used in dyeing, to fix a variety of vegetable colours, which otherwise would be fugitive. By means of this salt we are enabled to obtain the admired colour * of the ancients, called the Tyrian purple, which on pain of death none but the Cæsars could wear. It is of service in the manufacturing of candles, giving consistence and firmness to the tallow. It is employed in the cod-fisheries, when the fish are prepared for drying, having the property of preventing the salt from deliquescing. In the art of tanning it gives a firmness to the skins after they have become flaccid in the lime-pits. It is used also in other preparations of leather. Its efficacy in preventing the bad effects of damp atmospheric air on preserved fish has been mentioned: with the same design it has been used in preparing paper for the preservation of gunpowder; and when used thus, it is of further service, by preserving the paper from readily taking fire. But one of the most striking advantages of this important salt is in the preparation of acetate of alumine for the calico-printers; an article which, in the present improved state of the arts, the manufacturer cannot dispense with. It is prepared with acetate of lead, by a double decomposition. An easy way to prepare it is related in Rees's *new* Cyclopædia.

XXV.

Of Carbon and its Combinations.

Carbon, whether we regard it in its most simple state, the diamond, or in that of common charcoal, is not only indestructible by age, but in all its combinations, which are infinitely beyond our comprehension, still preserves its identity. In the state of carbonic acid it exists in union with earths and stones in unbounded quantities; and though buried for thousands of years beneath immense rocks, or in the centre of mountains, it is still carbonic acid; for no sooner is it disengaged from its dormitory than it rises with all the life and vigour of recent formation, not in the least impaired by its torpid inactivity during a lapse of ages. Is not the consideration of this subject calculated to afford a strong and satisfactory analogical argument in favour of human resuscitation?

XXVI.

Of Chemical Decomposition.

The changes which matter perpetually undergoes by the de-

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* See Introduction to Berthollet on Dyeing, page 19.

composition of all organized beings, probably gave rise to the ancient doctrine of transmigration. See pages 69 and 450.

> " The sacred seer with scientific truth,
> In Grecian temples, taught the attentive youth
> With ceaseless change how restless atoms pass
> From life to life, a transmigrating mass;
> Whence drew the enlighten'd sage the moral plan,
> That man should ever be the friend of man;
> Should eye with tenderness all living forms,
> His brother emmets, and his sister worms!"
>
> DARWIN.

XXVII.

Of the Manufacture of Shot.

The manufacture of small shot is curious, and will probably amuse the young reader. In melting the lead a small quantity of arsenic is added, which disposes it to run into spherical drops. "When melted, it is poured into a cylinder whose circumference is pierced with holes. The lead streaming through the holes, soon divides into drops which fall into water, where they congeal. They are not all spherical; therefore, those that are must be separated, which is done by an ingenious contrivance. The whole is sifted on the upper end of a long smooth inclined plane, and the grains roll down to the lower end. But the pear-like shape of the bad grains makes them roll down irregularly, and they waddle as it were to a side; while the round ones run straight down, and are afterwards sorted into sizes by sieves. The manufacturers of the patent shot have fixed their furnace, for melting the metal, at the top of a tower 100 feet high, and procure a much greater number of spherical grains, by letting the melted lead fall into water from this height, as the shot is gradually cooled before it reaches the water*." See pages 399 and 416.

XXVIII.

Of the Manufacture of White Lead.

Most of the manufactures of white lead are conducted somewhat similar to the method related at page 438; but at Tipton, near Dudley, there is a very large establishment for the preparation of white lead on a different principle. Muriate

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* Dr. Black, vol. ii. page 604.

of soda is there decomposed by means of litharge; and as the soda becomes disengaged, the muriatic acid combines with the litharge, and forms *muriate of lead.* I have reason to believe that carbonate of soda is employed for the decomposition of the latter muriate, and that from thence results the carbonate of lead, which is the product of the manufactory. The manufactories of earthen ware in the Staffordshire potteries are chiefly supplied with this lead. Great quantities of it are also exported to America.

XXIX.

Of Water-gilding.

Some persons may be glad to be informed how the process of water-gilding is conducted. It is done by previously cleaning copper intended to be gilt, with sand and weak aqua-fortis; after which the piece is plunged in a diluted solution of mercury; the mercury leaves its solution and precipitates itself upon the copper: this causes the amalgam of gold, which is afterwards spread on the piece, to adhere. When the amalgam of gold is uniformly spread, the piece is heated on charcoal, which volatilizes the mercury, and leaves the gold on the copper. See pages 324, 360, 374. The method practised by the Birmingham manufacturers may be seen in a paper of Mr. Collard's, printed in the ninth volume of the Philosophical Magazine. The processes for other kinds of gilding may be seen in Gren's Chemistry.

XXX.

Of Tin and Tinned Plates.

Tin is of use for covering copper and iron culinary utensils. See page 391 and 393. It is also employed in the formation of tin-plate. These are thin plates of rolled iron, which are covered with tin by the following process:—The iron plates, having been thoroughly cleaned by rubbing them with sand, are steeped in water for 24 hours, acidulated by bran or sulphuric acid. They are then made dry, and gently heated in an oven, being first rubbed over with grease, to prevent oxidizement. In this state they are immersed in melted tin, which not only adheres to the surface, but in a great measure penetrates the whole plate *. For a more particular account of these processes consult La Grange, vol. ii. 80. There are two kinds of tin known in commerce; viz. *block* tin and *grain* tin. Block tin is procured from the common tin ore, and is usually cast in blocks of about 320 pounds weight; after which it is taken to the proper offices to be assayed, where it receives the impression of a lion rampant, the arms of the earl of Cornwall, and which are necessary to make it saleable. Grain tin is found in small particles, in what is called the *stream tin ore*. It appears to have been washed from its original bed in remote ages. This kind of tin owes its superiority not only to the purity of the ore, but to the care with which it is washed and refined. Tin when taken to be stamped pays a duty of four shillings per hundred weight to the duke. From hence a vast income accrues to the prince of Wales. For a particular account of the management of the Cornish tin-mines, consult the sixth volume of Maurice's Indian Antiquities, and Mr. Taylor's communications in the Philosophical Magazine.

XXXI.

Wine Tests.

We are told that fraudulent wine merchants have sweetened their wines and cyders by the addition of lead. Dr. Watson relates that it was at one time a common practice at Paris. He directs how it may be detected. See his Chemical Essays, vol. iii. page 369. Methods of detecting this and other adulterations of wine may be seen in Dr. Willich's Lectures on Diet and Regimen, pages 357 to 362. The following is easy of application, and will be found effectual:—Equal parts of oyster-shells and sulphur may be heated together, kept in a white heat for 15 minutes, and, when cold, mixed with an equal quantity of cream of tartar; these are put into a strong bottle with common water to boil for an hour; and then decanted into ounce phials, adding 20 drops of muriatic acid to each. This liquor precipitates the least quantities of lead, copper, &c. from wines in a very sensible black precipitate. As iron might accidentally be contained in the wine, the muriatic acid is added to prevent its precipitation, and its being mistaken for the precipitate of lead. See pages 396—399.

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* Dr. Thomson, vol. i. 177.

XXXII.

Native Copper.

A mass of *native* copper has been found in a valley in the Brazils 2666 pounds weight. The description of it in the Memoirs of the Royal Academy of Sciences of Lisbon, is said to be very interesting, as the largest specimen of native copper that had ever been found before this weighs only ten pounds. Appendix to Monthly Review, vol. xxvii. N. S. 551.

XXXIII.

Of Iron.

There are several ways of analysing iron ores. An easy method has been suggested by Dr. Higgins; viz. by noting the quantity of hydrogen gas that is given out, by treating them with the usual mixture of sulphuric acid and water. This method will give, with very little trouble, a good comparative analysis. One part sulphuric acid to eight parts water is the proper proportion for use.

If an iron ore be suspected to contain sulphur, take two measures of the hydrogen gas produced by the iron ore in question, and add to them one measure of oxygen gas; then inflame these gases by electricity, and examine the water which is produced from their combustion. If litmus paper be reddened thereby, it is a proof that it is acidified, and that the ore contained sulphur—otherwise not.

Some valuable information on the manufacture of iron and steel, and on the methods of preparing coak, may be collected from a scarce duodecimo volume, by a Mr. Horne, entitled "An Essay on Iron and Steel." A quarto volume on the same subject, with engravings of furnaces, &c. has lately been imported by De Boffe from Paris, which is well spoken of.

Iron is found in solution in many natural springs; it gives the character to all our chalybeate waters; besides which there are some springs which contain iron in combination with sulphuric acid. These are called vitriolated waters. There are several in the kingdom, but those at Shadwell near London, and at Swansey in Glamorganshire, I believe, are the most important.

This metal is deposited magnetic, and nearly in its metallic state, by the Bath waters, which hold it in solution by some peculiar power that has hitherto escaped all investigation. See Dr. Gibbes on the Bath waters.

> "Hail, adamantine steel! magnetic lord!
> King of the prow, the plowshare, and the sword!
> True to the pole, by thee the pilot guides
> His steady helm, amid the struggling tides,
> Braves with broad sail the immeasurable sea,
> Cleaves the dark air, and asks no star but Thee."
> DARWIN.

XXXIV.

Of the Iron Manufactories.

Some idea of the extent and importance of the iron trade (see page 380), may be conceived from the following account of the iron works in South Wales:—"Merthyr Tydvil was a very inconsiderable village till the year 1755, when the late Mr. Bacon obtained a lease of the iron and coal mines of a district at least eight miles long, and four wide, for 99 years. Since then these mines have been leased by him to four distinct companies, and produce to the heirs of Mr. Bacon a clear annual income of ten thousand pounds. The number of smelting furnaces belonging to the different companies at Merthyr is about sixteen. Around each of these furnaces are erected forges and rolling-mills, for converting pig into plate and bar iron. These works have conferred so much importance on the neighbourhood, that the obscure village of Merthyr Tydvil has become the largest town in Wales, and contains more than twelve thousand inhabitants." Abridged from Malkin's Scenery, &c. of South Wales.

XXXV.

Of the Diamond.

"It will no doubt be demanded how it happens that pure carbon or diamond is so scarce, while its compounds in different states are so abundantly dispersed? To dispel the astonishment of those who might consider this a ground of distrust, I shall remind them that the aluminous earth is likewise one of the commonest substances, though the adamantine spar, no less rare than the diamond, is nevertheless alumine; that iron exists every where, under every form, excepting in the state of purity, and that the existence of *native* iron is still doubtful. The wonder respecting the diamond consists only in the opposition between facts and our opinions; it disappears in proportion as we discover and appropriate the powers of nature to produce the same effects*." See page 349.

XXXVI.

Of the Absorption of Caloric.

Dr. Black heated a quantity of water in a strong phial, closely corked, till its temperature rose ten degrees above 212°, its usual boiling point. On drawing the cork quickly, a small portion of water rushed out in vapour, and the temperature of the remaining fluid sunk instantly to 212°. Ten degrees of caloric, therefore, had been absorbed by the quantity of vapour that escaped. Mr. Watt, by heating water under the pressure of a strong iron vessel, raised its temperature to 400°; yet still when the pressure was removed, only part of the water was converted into vapour, and the temperature of this vapour, as well as that of the remaining fluid, was no more than 212°. There were therefore 188 degrees of caloric absorbed in an instant, by the formation of the vapour which had no effect on the thermometer. Murray's Elements.

XXXVII.

Of the Indestructibility of Matter.

That the Author of nature had so constituted the world that none of its elements should be subject to destruction, might have been supposed by the ancients; but, till the present advanced state of the science of chemistry, no proof of this interesting fact could have been adduced. This is one of the many instances of the tendency which this valuable science has to enlarge the mind. In addition to the facts which have been already noticed it may be remarked, that provision has been made even for the restoration of the fallen leaves of vegetables, which rot upon the ground, and, to a careless observer, would appear to be lost for ever. Berthollet has shown by experiment, that whenever the soil becomes charged with such matter, the oxygen of the atmosphere combines with it, and converts it into carbonic acid gas. The consequence of this is, that this same carbon in process of time is absorbed by a new race of vegetables, which it clothes with a new foliage, and

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* Thomson's Notes on Fourcroy, vol. iii. page 201.

which is itself destined to undergo similar putrefaction and renovation to the end of time.

> "Link after link the vital chain extends,
> And the long line of BEING never ends."

How insignificant do the most stupendous works of art appear, when compared with the beautiful simplicity of these masterpieces of Nature! See page 350.

XXXVIII.

Of the Caloric of Combustion.

Dr. Crawford determined by numerous experiments, that the evolution of caloric which attends combustion, is owing to *change of capacity*. He found that the capacity of oxygen gas for caloric, is much greater than the capacities of combustible bodies; he likewise ascertained that the capacity of the compound resulting from the combustion is always much less than that of the oxygen gas; it is therefore evident, that caloric *must* be rendered sensible during combustion, and that it is from the oxygen gas and not from the combustible that it must be evolved.

XXXIX.

Of Pit-coal.

Dr. Darwin was of opinion that our pit-coal has all been sublimed more or less from the clay with which it was at first formed, in the decomposition of morasses*. But from the various changes which combustible substances undergo, it must be impossible to speak with certainty on this subject. Naphtha, which is found in great abundance in Persia, is as fluid and transparent as water; but when exposed to the air it becomes yellow, and then brown; its consistence is increased, and it passes into *petroleum*. Petroleum is found native in many countries, and by an exposure to the air becomes *mineral tar*. Mineral tar is also found native, which by exposure to the air passes into *mineral pitch* and *maltha*. By further induration this passes into *asphaltum*, which substance is likewise found native in many parts of the world. Common coal is a composition of some of these bitumens and charcoal. The

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* Note, page 90, part i. of his Botanic Garden.

French jet and the English cannel coal are both so hard that they are susceptible of polish, and are frequently wrought into trinkets. See Notes pages 326, 327.

XL.

Of the Glow-worm.

"The glow-worm is the wingless *female* of a beetle insect. The male is of a dusky hue, without much beauty or peculiarity of markings. The female is more like the larva or grub of a beetle, than a perfect full grown insect. The light, which is of a beautiful sulphur colour, proceeds from the three last rings of the body. See page 464. From the circumstance of the male being a winged animal, and the female not, it was necessary that some contrivance should be had recourse to for directing the rambler to his sedentary mate. What more beautiful, and at the same time sufficient guide could possibly be contrived, than this self-lighted hymeneal torch?"

> "Thine is an unobtrusive blaze,
> Content in lowly shades to shine;
> How much I wish, while thus I gaze,
> To make thy modest merit mine!"
>
> Mrs. Opie.

XLI.

Of Siliceous Fossils.

Although this is not professedly a mineralogical work, the following brief account of some of the more common fossils will perhaps not be unaceptable. We begin with those whose chief ingredient is silex.

Quartz is composed chiefly of silex, and forms many of our primitive mountains. It occurs of various colours and of a variety of shapes. According to Bergman it is composed of 93 parts of silex, 6 of alumine, and 1 of oxide of iron. Its specific gravity is 2,6. When perfectly transparent, it is called Rock crystal. This is composed of 93 silex, 6 of alumine, and 1 of lime. When quartz occurs of a purple colour it is called amethyst.

Chalcedony is of a gray or brown colour with various shades of yellow, blue, or green, in stalactical or spherical masses. It consists of 84 parts of silex, and 16 of alumine, with a small portion of iron. When of a flesh-red colour, semi-transparent and amorphous, it forms CORNELIAN; when stained with dark coloured spots or arborizations, MOCHO *stones*. The OPAL, the PITCH STONE, and the HYALITE are fossils of the same family. JASPER is a siliceous fossil which exhibits great variety in its appearances. It is generally composed of about 60 parts silex, 30 of alumine, and 10 parts of potass, magnesia, and oxide of iron. Its colours are various, and it is susceptible of a high polish. Its specific gravity is from 2.3 to 2.7. Where it is composed of alternate broad stripes or layers of different colours, it is termed RIBBAND JASPER; the variety which is found in spheroidal masses, and exhibits various colours, or shades of the same colour in concentric and alternating stripes or layers, is termed ÆGYPTIAN PEBBLE.

PUDDING STONE is a collection of rounded pebbles cemented together by siliceous matter intermixed with iron. It takes a fine polish, and possesses a considerable degree of hardness.

GARNET is of a deep red colour, sometimes varying to brown, black, or violet. Its specific gravity is from 4 to 4.3. The common red kind consists of silex 48, alumine 30, lime 11, iron 10. LEUCITE, or white garnet, is generally in small opaque crystals, and contains 20 per cent. of potass.

LAPIS LAZULI is a stone of a rich blue colour, having little lustre, but susceptible of a fine polish. Its specific gravity is 2.7; its colour is occasioned by a blue sulphuret of iron. It occurs massive, and is so hard as to scratch glass. According to Klaproth it is composed of 46 silex, 14.5 of argil, 28 of carbonate of lime, 6.5 of sulphate of lime, 3 of oxide of iron, and 2 of water. That beautiful fine pigment known by the name of ultramarine is made from this fossil.

XLII.

Of Aluminous Fossils.

The aluminous fossils differ from the aluminous earths in having the hardness of stones and in not falling into powder when immersed in water. The principal are the following.

CORUNDUM, or adamantine spar, is distinguished from every other stone by its great hardness, which is such that it is used for polishing even the diamond. Its specific gravity is from 3.9 to 4.1. It consists of 84 to 89 of alumine, 5 or 6 of silex, and from 1 to 7 of oxide of iron.

LILLIALITE, or LEPIDOLITE, is of a violet blue or purple colour, and, when in thin laminæ, of a silvery white; it has a pearly lustre with a slight transparency. Its specific gravity is 2.8. It is composed of about 55 parts of silex, 38 of alumine, 4 of potass, and 1 of iron and manganese, with 2 or 3 of water.

Cyanite is of a blueish gray colour, with streaks of deep blue. Its specific gravity is 3.5. It consists of 66 alumine, 13 magnesia, 12 silex, 1 lime, and 5 of iron.

Hornblende. Common hornblende is amorphous, of a gray or black colour, and possesses considerable hardness. Its specific gravity is from 3.6 to 3.8. By heat it may be fused into glass. According to Kirwan, it consists of silex 37, alumine 22, carbonate of magnesia 16, carbonate of lime 2, and oxide of iron 23.

Trap. Under this name are comprehended several varieties of stones, which agree in their general characters. It is found in large masses, of a gray, blue, or purplish black colour, destitute of lustre or transparency, and presenting generally a texture composed of granular concretions. **Whinstone** is a variety of this fossil.

Basaltes is a similar fossil; but it has a greater specific gravity than trap, and is always in large masses of a regular form, generally columnar. According to Klaproth it is composed of 44.5 silex, 17 alumine, 20 oxide of iron, 9.5 of lime, 2.6 soda, and 6 manganese and water. See page 287. and Additional Notes, No. 14.

Slate, the last of the aluminous stones, is of a blue or grayish colour, with little lustre and scarcely any transparency: it is composed of alumine, silex, lime, magnesia, and oxide of iron, united in various proportions, in the different specimens.

XLIII.

Of Magnesian Fossils.

The magnesian fossils are distinguishable by a peculiar softness and unctuosity, and by being destitute of the hardness and infusibility of the siliceous genus.

Chlorite is a fossil of a green colour and scaly texture, without lustre. It occurs both amorphous and crystallized, and consists of magnesia 39, silex 42, alumine 6, lime 1.5, iron 10, and water 1.5.

Talc has a plated texture, the lamellæ being easily separated from each other. These lamellæ are flexible, but not elastic; their colour is a greenish white, with sometimes a tinge of red. The fossil consists of 50 silex, 44 magnesia, and 6 of alumine. Its specific gravity is 2.7 to 2.8.

Steatite, or soap rock, exist sin various states of induration. Its specific gravity is 2.6. It always feels soft and greasy; is of a white, yellowish, or greenish gray colour; often spotted or veined; with little lustre or transparency. It is composed of silex, magnesia, alumine, oxide of iron, and water, in various proportions.

SERPENTINE is of a dark green colour, sometimes red or blueish gray, with spots or veins of other colours, through its substance; without lustre, but susceptible of a fine polish. Its specific gravity is 2.6. It is always found amorphous. It is composed of silex 45, magnesia 33, iron 14, carbonate of lime 6, alumine and water 2.

ASBESTUS is distinguished by its fibrous, or striated texture. Its colour is green, greenish gray, or yellowish gray. It does not effervesce with acids. Its specific gravity is 2.5. Its component parts vary, consisting of silex, magnesia, iron and alumine; the silex being generally in the largest proportion. See page 146.

AMIANTHUS is a similar fossil, differing from asbestus in its filaments being more separated and flexible. According to Mr. Chenevix it is composed of silex 59, magnesia 25, lime 9, alumine 3, iron 2.

MOUNTAIN CORK is of a white, yellowish, gray, or brown colour; without lustre or transparency; and so light as to swim upon water; its specific gravity being from 0.68 to 0.99. It consists of silex 56, carbonate of magnesia 26, alumine 2, carbonate of lime 13, and oxide of iron 3.

JADE is of a dark green colour, verging often to blue. From its supposed medical virtues it was formerly called NEPHRITIC STONE. Its specific gravity is 2.9. It consists of silex 47, carbonate of magnesia 38, alumine 4, lime 2, and iron 9. The inhabitants of New Zealand make their hatchets and other edge tools with this stone.

BORACITE occurs in small cubic crystals, of a grayish white colour. It is a compound of magnesia and lime, with boracic acid; its proportions being 13 of magnesia, 11 of lime, and 68 of acid, with 1 of silex, 1 of alumine, and 1 of iron. Its specific gravity is 2.560. This fossil has been found near Luneberg, seated in a bed of sulphate of lime.

XLIV.

Of Calcareous Fossils.

GYPSUM, or Plaster of Paris, exists native in considerable quantity, and forms immense strata in various parts of the world. Its specific gravity is 2.3. It consists of 32 parts of lime, 46 of sulphuric acid, and 22 of water. Some of the varieties contain carbonate of lime, alumine, iron, and silex.

FLUOR SPAR is found both amorphous and crystallized, and is susceptible of a fine polish. Its specific gravity is about 3.1. Its colours are very various, and in general beautiful. According to Scheele it is composed of 57 of lime, 16 of fluoric acid, and 27 of water.

APATITE, which is a phosphate of lime, occurs crystallized and amorphous. Its specific gravity is 3.2. Its colour is gray, green, red, or purple. It consists of 55 of lime, and 45 of phosphoric acid.

CALCAREOUS SPAR is crystallized, amorphous, and stalactical. Its specific gravity is 2.7. The crystals are distinguished by their laminated texture, and by their fragments being rhomboidal and possessing the property of *double refraction*. They have often the transparency of the siliceous crystals, but want their hardness, being easily scratched with a knife. They consist of 55 lime, 34 carbonic acid, and 11 of water. *Amorphous* calcareous spar has less transparency and lustre, and its fracture presents distinct granular concretions.

The *Stalactites* are distinguished by their fibrous or striated texture, and their peculiar shapes; being formed at the tops of caverns, by deposition, from water filtering through the roof, loaded with carbonate of lime. According to Bergman they are composed of 64 parts lime, 34 of carbonic acid, and 2 of water. Their specific gravity is 2.7. The *Stalagmites* are similar depositions, formed by the water dripping on the floor of the cavern.

Marble is distinguished from the preceding varieties by being amorphous, existing in large strata, and by greater density and hardness; the latter qualities enable it to take a fine polish. Marbles appear under a variety of forms distinguished by colours, impressions, and fineness of grain. Their specific gravity is generally about 2.7, but their component parts differ.

White marble is nearly pure carbonate of lime; the coloured kinds contain silex, alumine, oxide of iron, and sometimes magnesia and barytes. Abridged from Murray.

———————" dissolving shells distill
From the loose summits of each shatter'd hill,
To each fine pore, and dark interstice flow,
And fill with liquid chalk the mass below;
Whence sparry forms in dusky caverns gleam
With borrowed light, and twice refract the beam;
While in white beds congealing rocks beneath
Court the nice chisel, and desire to breathe;
Or, fused by earth-born fires, in cubic blocks
Shoot their white forms, and harden into rocks."

DARWIN.

XLV.

Vegetable Poison.

In the royal cabinet of Louis the Sixteenth, at Paris, there were arrows whose points were steeped in the juice of so venomous a plant, that, though exposed to the air for many years, they will by the slightest puncture in a few minutes destroy the stoutest animal that exists. The blood of the victim, trifling as may be the wound, instantly congeals; but, if a small quantity of sugar be immediately swallowed by him the circulation is as quickly restoted*. See page 7.

> "Nature, compell'd by a superior cause,
> Now breaks her own eternal laws,
> Now *seems* to break them, and obeys
> Her sovereign king in different ways."
> WATTS'S LYRICS.

XLVI.

Predatory Insects.

Having already considered (pages 68, 69, and 84) several of those means by which the atmosphere is regularly renovated, it may not be amiss to remark, that the Deity has also provided an innumerable multitude of predatory insects to assist in the accomplishment of the same purpose. These remove the noxious matter that otherwise might rest upon the surface of the earth; and they convert to their own support, even such excrementitious substances, as by the exhalation of their putrid miasmata, would in time totally destroy the whole animal creation.—Is it possible for an unprejudiced mind to avoid being charmed with this beautiful œconomy of nature; or for those sapient philosophers to escape our pity, who *endeavour* to persuade themselves, that to chance only, they are indebted for all these congruities?

> "To me, the laurel'd wreath that murder rears,
> Blood-nursed, and water'd by the widow's tears,
> Seems not so foul, so tainted, and so dread,
> As waves the night-shade round the sceptic-head."
> CAMPBELL.

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* St. Pierre's Studies of Nature, vol. i. 18.

XLVII.

Of some of the Effects of Respiration.

The oxygen of the atmosphere deprives the blood of its excess of carbon and hydrogen: with the first it forms carbonic acid, and with the latter, water; and these are thrown from the lungs in the act of respiration. As carbonic acid has the property of sweetening putrid substances, by uniting chemically with putrid vapour, may it not operate in this way with regard to the putrid exhalations from the lungs, and render the breath of some persons inoffensive, which would otherwise be intolerably fetid and pestilential*? See page 77.

XLVIII.

Of Snow.

Nature has furnished snow with the power of absorbing and combining with a large portion of oxygen; hence it improves land by lying upon it. The snow melting and penetrating into the softened earth communicates to it oxygen, and thus promotes the germination of seeds. The carbon of the earth combining with the oxygen is converted into carbonic acid, and thereby acquires more solubility; while the water contributes to excite that activity which had been rendered dormant in the roots by the cold. It is this property of carbon that deprives water of the superabundant oxygen, that would render it prejudicial to health, and unfit for the purposes of life. Thus what would otherwise be injurious to us is improved by the ground, and gives at the same time power and activity to the mould †. See note page 115.

XLIX.

Manufacture of Sugar.

The sugar cane affords most of the sugar which is consumed in Europe. The ripe canes are crushed between two iron cylinders placed perpendicularly. The expressed juice falls on a plate beneath, whence it flows into a caldron, where

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* Dr. Lambe on Constitutional Diseases.

† Driessen on the Nature of Snow.

it is boiled with wood-ashes and lime, and the scum taken off. This boiling with ashes and lime is repeated in three other boilers, and this process converts it into syrup. It is then strongly boiled with lime and alum, and when sufficiently concentrated is poured into hogsheads pierced at the bottom with many holes, to let off the molasses, which will not crystallize. These holes are afterwards stopped with canes as we see them when imported. The sugar, as it cools, becomes solid in the casks, and is called *muscovado* sugar. It afterwards undergoes several refinings in order to form it into loaf sugar. See Thomson's Fourcroy, 1800, vol. iii. 116.

It should be remembered that oxygen is absolutely necessary for the formation of sugar, which is a vegetable oxide. If it were deprived of the greater part of this oxygen, it would lose its sweetness, and would be no longer sugar, but a singular kind of substance, possessing properties more analogous to gum than sugar. Mr. Cruickshank has effected this change by means of phosphuret of lime, which has a very strong attraction for oxygen, though he was not able to reproduce sugar by the union of gum with oxygen. See pages 171 and 347. See also an account of these experiments in Dr. Rollo's Treatise on Diabetes.

L.

Coak Ovens.

As the success of several manufactures depends on the procuring good coak, (see note page 514). I feel pleasure in having it in my power to furnish a description of the kind of oven made use of in the north of England for coaking the refuse small-coal, which before the adoption of this method was entirely useless.

At the Duke of Norfolk's colliery near Sheffield several of these ovens are built on the side of a hill, occupying spaces formed within the bank. Each oven is a circular building, 10 feet in diameter within, and the floor laid with common brick set edgeways. The wall of the oven rises 19 inches perpendicular above the floor, and the whole is then covered with a brick arch which rises 3 feet 5 inches more, forming nearly a cone, whose base is 10 feet, and whose apex is 2 feet, if measured within. This opening of 2 feet at the top, is left for the convenience of supplying the oven with coal, and to serve as a chimney during the process. The whole height of the building from the floor is five feet, and the wall, which is 18 inches in thickness, is built with good brick, and closely laid, that no air may get in through any part of the work.

The floor is elevated three feet above the ground, for the convenience of placing a carriage under the door-way to receive the coak as it is raked from the oven. When the oven is thus finished, a strong perpendicular wall of common unhewn stone is thrown round it, of about 20 inches in thickness, and carried up the whole height of the oven, forming a complete square. The four corners between the circular building and these outward walls, are then filled with soil or rubbish and well rammed, to give greater firmness to the work, and the more effectually to exclude atmospheric air.

When these ovens are once heated, the work goes on night and day without interruption, and without any further expense of fuel. It is conducted thus :—Small refuse coal is thrown in at the circular opening on the top, sufficient to fill the oven up to the springing of the arch ; it is then leveled with an iron rake, and the door way built up with loose bricks. The heat which the oven acquires in the former operation is always sufficient of itself to light up the new charge ; the combustion of which is accelerated by the atmospheric air that rushes in through the joints of the loose bricks in the door way. In two or three hours the combustion gets to such a height, that they find it necessary to check the influx of atmospheric air ; the door-way is therefore now plastered up with a mixture of wet soil and sand, except the *top* row of bricks, which is left unplastered all night. Next morning (when the charge has been in 24 hours) this is completely closed also ; but the chimney remains open till the flame is gone, which is generally quite off in 12 hours more ; a few loose stones are then laid on the top of the chimney, and closely covered up with a thick bed of sand or earth All connection with the atmosphere is now cut off, and in this situation the whole remains for 12 hours, to complete the operation. The door way is then opened, and the coaks are raked out into wheelbarrows, to be carted away. The whole takes up 48 hours ; and as soon as the coaks are removed, the ovens are again filled with coal for another burning. About 2 tons of coals are put in for each charge. These coaks are ponderous, extremely hard, of a light gray colour, and shine with metallic lustre. They are used in those manufactures that require an intense heat. When coak is required to be more of the nature of charcoal, the process is conducted in a different manner. The small coal is thrown into a large receptacle similar to a bakers oven, previously brought to a red heat. Here the door is constantly open, and the heat of the oven is sufficient to dissipate all the bitumen of the coals, the disengagement of which is promoted by frequently stirring with a long iron rake. The coak from these ovens, though made with the same kind of coal, is very different from that produced by the former operation; this being intensely black, very porous, and as light as pumice stone. I am indebted to Mr. Curr, steward to his Grace the Duke of Norfolk, for these particulars, who very politely attended me through the works in the year 1802, and assisted me in taking the necessary measurements, &c.

LI.

Of the Uses of Diamond.

The lapidaries employ a considerable quantity of diamond in powder, which they use with steel instruments, to divide pebbles and precious stones. The small pieces of diamond of which the powder is made, are worth 28 shillings a carat. The use of the diamond in this way is very extensive. Had nature withheld the diamond,—the pebble, the agate, and a variety of other stones, would have been of little value, as no other substance is hard enough to operate upon them. In this way rock crystal from Brazil is divided into leaves, and ground and polished with diamond dust for spectacles, and other optical instruments. See page 324.

LII.

Of the Effect of Oxygen upon Colours.

Several of the effects of oxygen have been mentioned in different parts of this work; but its action on colouring substances has not been noticed, though it is various and striking. When woollen cloths are taken out of an indigo vat, they are of a green colour; but they are scarcely exposed to the atmospheric air for one minute, before they imbibe a sufficient portion of oxygen to change that colour to a deep blue. In like manner the whelk (the *buccinum* of Linnæus), which is used to dye purple, undergoes a change equally extraordinary. The liquor, though naturally yellow, becomes oxidized by exposure to the sun and air, passes through various shades of yellow, green, crimson, &c., and at length becomes purple. A good *black* cannot be given to cloth, without frequent exposure to the air. Light has a great affinity for oxygen: hence clothes frequently fade and lose their colours by the abstraction of oxygen. That part of the furniture of a bed which has been exposed to the sun will often be entirely faded, while those parts which have not been so exposed will retain their original colours. All this arises from the same cause; for the oxygen which existed in a solid form is rendered aëriform by the rays of the sun, and goes off in the state of oxygen gas. See page 463.

LIII.

Of the Gases emitted in Respiration.

Having shown that sheet of the work which contains page 83 to a friend of mine, an ingenious chemist, he suggested that those remarks on the *levity* of nitrogen gas evolved from the lungs in respiration, would have more force, were I to contrast this character with the superior specific gravity of carbonic acid gas, which is ejected at the same instant. For during that *remarkable* interval that always occurs in breathing, there is sufficient time allowed for these noxious fluids to separate; the first to ascend, while the other preponderates, leaving a space for a fresh current of uncontaminated atmospheric air. Thus every thing is prepared without any care or forethought of ours for a new inspiration.

> "The air inhal'd is not the gas
> That from a thousand lungs reeks back to thine
> Sated with exhalations rank and fell,
> Which, drunk, would poison the balsamic blood,
> And rouse the heart to ev'ry fever's rage—
> But air that trembling floats from hill to hill,
> From vale to mountain, with incessant change
> Of purest element."
>
> ARMSTRONG.

LIV.

Of Lutes.

Glazier's putty is a very good lute for all common purposes, but it is necessary that the whiting be made thoroughly dry before it be mixed with the oil. Linseed oil and sifted slacked lime, well mixed, and made thoroughly plastic, form an excellent coating for retorts: if made thicker, this mixture is an impenetrable luting, that is not liable to crack.

Dr. Black recommends a mixture of four parts sand, and one of clay, except where it is to be exposed to an intense heat, and in such situations to use six parts of sand to one of clay.

For *fire*-lute, Mr. Watt directs the use of porcelain clay from Cornwall (not pipe-clay), to be pounded small, and mixed up to the consistence of thick paint, with a solution of two ounces of borax in a pint of hot water. For want of this peculiar kind of clay, slacked quick-lime, mixed up in the same manner, may be used. This may be kept ready mixed in a covered vessel. For *cold*-lute he directs to take equal parts by measure of the above clay and wheat flour, and to mix them to a proper consistence with cold water. This is more tenacious than his fire-lute, but does not keep so well.

A very excellent lute for many purposes may be made by beating up an egg, both the white and the yolk, with half its weight of quick-lime in powder. This lute is to be put upon a piece of linen, and applied as usual. It dries slowly, but becomes very compact, and acquires great hardness.

A mixture of martial pyrites and muriate of ammonia forms a good lute for stopping the cracks in iron utensils; but the following artificial compound is preferred, on account of the exact proportions of the ingredients being more easily ascertained. To two pounds of iron turnings or filings, add one ounce of sal ammoniac, and one ounce of flour sulphur; blend the mixture with water till the whole is of a proper consistence, and use it fresh. This lute is employed by Mr. Watt to stop the joints of steam engines, and other large machinery.

LV.

Of the extreme Hardness of Ice in some Countries.

The following narration will show the solidity that water is capable of acquiring when divested of a large portion of its caloric:—During the severe winter of 1740, a palace of ice, fifty-two feet long, sixteen wide, and twenty high, was built at Petersburgh, according to the most elegant rules of art. The river Neva afforded the ice, which was from two to three feet thick, blocks of which were cut, and embellished with various ornaments. When built up, the different parts were coloured by sprinkling them over with water of various tints. Six cannons made of, and mounted with, ice, with wheels of the same matter, were placed before the palace; and a hempen bullet was driven by one of these cannon, in the presence of the whole court, through a board two inches thick, at the distance of sixty paces[*]. See page 137.

> "No forest fell,
> Imperial mistress of the fur-clad Russ,
> When thou wouldst build—no quarry sent its stores
> T' enrich thy walls: but thou didst hew the floods,
> And make thy marble of the glassy wave.
> Silently as a dream the fabric rose;
> Ice upon ice the well adjusted parts
> Were soon conjoined; nor other cement ask'd
> Than water interfus'd to make them one.
> Lamps gracefully disposed, and of all hues,
> Illumin'd ev'ry side. Long wavy wreaths
> Of flowers, that fear'd no enemy but warmth,
> Blush'd on the pannels, which were once a stream,
> And soon to slide into a stream again." COWPER.

LVI.

A new Kind of Gunpowder.

Notwithstanding the accident which happened in France in the year 1788 (see note ‡, page 269), the French have since, as I have been informed, actually employed, in one of their campaigns, gunpowder made with oxygenized muriate of potass, instead of salt petre. That this is practicable has been proved in this country, by the Rev. Alexander Forsyth, an excellent chemist of Belhelvie, in Aberdeenshire, Scotland. This gentleman, who has lately taken out a patent for a new kind of gun-lock, to be used without a flint, and has contrived to inflame such gunpowder merely by percussion, informed me that, ten years ago, he discovered a method of making this gunpowder; and that he has himself been in the habit of using it ever since, in killing game. The gun-lock is calculated for firing cannon as well as musquetry; it is contrived to hold 40 primings of such powder; and the act of raising the cock primes the piece. Though each charge of priming contains only an eighth of a grain of oxygenized muriate of potass, that alone makes a very loud report; and the principle of the lock is such, that it can never possibly miss fire. This effect is entirely attributable to the large portion of oxygen, which is condensed in this very singular salt.

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[*] M. de Bomare.

LVII.

Of the Efficacy of Water in Vegetation.

That vegetables will grow in woollen cloth, moss, and in other insoluble media, besides soils, provided they be supplied with water, has been repeatedly shown since the days of Van Helmont and Boyle: but the experiments of a modern author, from their apparent correctness, seem more highly interesting and conclusive.

Seeds of various plants were sown in pure river-sand, in litharge, in flowers of sulphur, and even among metal, or common leaden shot; and in every instance nothing employed for their nourishment but *distilled water*. The plants throve, and passed through all the usual gradations of growth to perfect maturity. The author then proceeded to gather the entire produce, the roots, stems, leaves, pods, seeds, &c. These were accurately weighed, dried, and again weighed, then submitted to distillation, incineration, lixiviation, and the other ordinary means used in a careful analysis. Thus he obtained from these vegetables all the materials peculiar to each individual species, precisely as if it had been cultivated in a natural soil,—viz. the various earths, the alkalies, acids, metals, carbon, sulphur, phosphorus, nitrogen, &c. He concludes this very important paper, nearly in these extraordinary words: "*Oxygen* and *hydrogen*, with the assistance of solar light, appear to be the only elementary substances employed in the constitution of the whole universe: and that Nature, in her simple progress, works the most infinitely diversified effects by the slightest modifications in the means she employs. See "*Recherches sur la Force assimilatrice dans les Végétaux*," par M. Henri Braconnot, *Annales de Chimie*, Fev. et Mars 1807.

LVIII.

Of the Agencies of Galvanism.

The experiments of professor Davy, published in the first part of the Philosophical Transactions for 1807, have thrown considerable light on the agencies of electricity and galvanism.

First. In opposition to the assertions of Pacchiani and others, he has demonstrated that muriatic acid is not produced in water by the agency of galvanism, but that water "chemically pure, is decomposed into gaseous matter alone, into oxygen and hydrogen."

Secondly. By the agency of galvanism he decomposed sulphate of lime, sulphate of strontian, fluate of lime, and other solid bodies, insoluble, or difficultly soluble in water. In each case, the earth was found in one vessel and the pure acid in the other. Even glass was decomposed, and part of its alkali exhibited entire. Sulphuric, muriatic, nitric and phosphoric salts were decomposed with more rapidity: the acids in a certain time collected in the tube containing the positive wire, and the alkalies and earths in that containing the negative.

Thirdly. He connected a small cup, made with sulphate of lime, with a cup of agate, by a piece of asbestus; and filling both with purified water, made a platina wire in the cup of sulphate of lime transmit the electricity from a power of 100 plates; a wire in the agate cup received it. In about four hours a strong solution of lime was found in the agate cup, and sulphuric acid in the cup of sulphate of lime. By reversing the order, and carrying on the process for a similar time, the sulphuric acid appeared in the agate cup, and the solution of lime on the opposite side.

Fourthly. Acid and alkaline substances passed through water containing vegetable colours, without affecting them; and the usual chemical affinities were so far destroyed or suspended by the agency of galvanism, that sulphuric acid was passed through a solution of ammonia without combining with it. In like manner the alkalies and earths were transmitted through acids, without combination.

From these and similar results, it appears that "hydrogen, the alkaline substances, the metals, and certain metallic oxides, are *attracted* by negatively electrified metallic surfaces, and *repelled* by positively electrified metallic surfaces; and contrariwise, that oxygen and acid substances are attracted by positively electrified metallic surfaces, and repelled by negatively electrified metallic surfaces; and these attractive and repulsive forces are sufficiently energetic to destroy or suspend the usual operation of elective affinity." Mr. Davy concludes this most important paper by suggesting, that this new method of decomposition may, probably, be introduced with advantage into manufactures; and imagines that he shall be able to refer several natural phænomena to this source, which have been hitherto inexplicable. I am happy to find that he intends to continue these very interesting experiments.

LIX.

Of the Origin of Caloric.

The author of a modern work entitled "Physical and Metaphysical Inquiries" imagines that caloric is *not* transmitted from the sun; but is a subtle fluid, originally belonging to our earth. The arguments, by which he supports this opinion, appear to me to have great weight; but I must refer the reader to the work itself, and content myself with merely copying the conclusion he draws from these premises: "This view of the nature of caloric," he says, "is more correspondent with the general character of matter, than those generally entertained. It still represents the sun as the great agent in the production of heat, without supposing it to be an enormous mass of fire. We have only to consider the sun as the great storehouse of light; a power indeed the most active in nature, but no ways destructive. It shows that light produces heat merely by exciting an insensible action betwixt caloric and the particles of matter contained in bodies. It accounts for the want of heat in the upper regions of the atmosphere by the want of sufficient matter to produce the action of caloric. It destroys the absurd opinion concerning transmitted and conducted heat, so contrary to the invariable characters of all the material powers. It shows that caloric is not an exception to all the other kinds of matter, but that, like its fellows, it exists in other characters besides that of heat. It enables us to solve the great difficulty concerning the distribution of *heat* among the different planetary bodies: for, according to this view, those nearest the sun may have no more than those at the most remote distance. We have only to suppose the quantity of caloric to be proportioned to the distance; and if a *small* quantity exists in the planet Mercury, no more heat may be excited than is done by a *larger* quantity in Saturn."

Mr. Bell, in his System of Anatomy, denies that animal heat is preserved entirely by the inspiration of atmospheric air, and advances a new theory, which he supports by several striking facts. See Bell's Anat. vol. ii.—article *Blood.*

LX.

Of the Barometer.

As the mercury in a barometer rises or falls in consequence of the variation in the weight of the atmosphere, this instrument has been made use of to measure the height of mountains, and by aëronauts, to ascertain the height they ascend in the air. The barometer varies about an inch for every 600 feet of ascent above the earth's surface. See page 63, and Additional Notes, No. 12.

LXI.

Of the Colour of the Blood.

The colour which the blood acquires by the absorption of oxygen may be accounted for on chemical principles. Blood contains much iron, and this iron is converted into red oxide by the oxygen gas which it receives from the lungs. If the coagulum of the blood be washed, it may be rendered colourless; but then it will be found by chemical tests to contain no iron. It has lately been supposed that the colour of the blood is occasioned by a phosphate of iron, that has the property of giving out part of its oxygen to the system, without its being entirely decomposed. This has given rise to the practice of prescribing phosphate of iron in cases where the blood is deficient in red particles. See page 77, and Additional Notes, No. 8 and 9.

> " When air's pure essence joins the vital flood,
> And with phosphoric acid dyes the blood,
> Contractile tubes the transient heat dispart,
> And lead the soft combustion round the heart."

LXII.

Of Copper.

Tin mines as they deepen, often produce copper; and formerly, when they had occasion to raise this ore in order to obtain the tin, it was thrown aside as of no value, under the name of *poder*. The present race of miners is profiting by the ignorance of their forefathers. This shows of what importance it is to determine, by chemical analysis, the nature of every substance which passes under the miner's observation. See Note, page 376.

LXIII.

Theory of Rain, &c.

I am favoured with the following theory to account for the rain that accompanies lightning, from Mr. Wm. Finch jun.

of Birmingham, a very young chemist of promising hope, and grandson of Dr. Priestley: "We know," he says, "that caloric enables the air to hold a large portion of water in solution:—now may not the electric fluid also act in the same way? If so, we see how it is that rain accompanies lightning: for, when the clouds part with their electricity, they cannot hold an equal quantity of water, and consequently the superabundant moisture falls down in rain." To the same ingenious youth I am likewise indebted for the note, page 82, explaining why we feel cold when naked. From the same source I also learn, that the new French theory of the formation of sulphuric acid, announced in Nicholson's Journal for June last, has been tried by a company of oil of vitriol makers in Birmingham, on a large scale, and that it entirely failed. Not one drop of acid was formed, although a current of nitrous gas was continually thrown into the chamber, where sulphur was burning, for two days and nights.

LXIV.

Of Twilight.

The reader is requested to correct with a pen page 54 line 10 of the Notes, and for *reflected* write *refracted*; also, page 64, line 2 of the notes, for *this reflection*, read *refraction*. The rays of a luminous body when they fall upon a transparent body, do not afterwards go directly in the same straight lines, but are refracted or bent, and proceed as though they had been propagated from another point. And if the medium on which they fall be denser than that from which they proceeded, they are bent towards a line perpendicular to the surface whereon they fall at the point of incidence; but if it be a rarer medium, in their bending they recede from the perpendicular*. Thus the gases that compose our atmosphere,

> "With airy lens the scattered rays assault,
> And bend the twilight round the dusky vault."

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* See Ferguson's Optics, page 204.

CHEMICAL TABLES.

Table of the Quantities of Acids and Bases which mutually neutralize each other: calculated by Berthollet from the new Tables published by Richter.

Bases.		Acids.	
Alumine	525	Fluoric	427
Magnesia	615	Carbonic	577
Ammonia	672	Sebacic	706
Lime	793	Muriatic	712
Soda	859	Oxalic	755
Strontian	1329	Phosphoric	979
Potass	1605	Formic	988
Barytes	2222	Sulphuric	1000
		Succinic	1209
		Nitric	1405
		Acetic	1480
		Citric	1683
		Tartareous	1694

Note. The intention of this table is, that if an article in one of these two columns is taken—for example, potash—to which the number 1605 corresponds, the numbers of the other column will show how much of each acid is required to neutralize these 1605 parts of potash: viz. they will require 427 parts of fluoric acid, or 577 of carbonic acid, or 1480 of acetic acid, &c. In like manner, if an article of the second column be taken, the first column will show how much earth or alkali will neutralize it. By means of the rule of three this table may be applied to any quantity of either of the above substances.

Table of the Affinities of sundry Bases for four of the Acids, according to their Intensity.

I. *Sulphuric Acid.*

	Intensity.
Ammonia	383
Magnesia	171
Lime	143
Soda	127
Potass	82
Strontian	72
Barytes	50

II. *Nitric Acid.*

	Intensity.
Ammonia	245
Magnesia	209
Lime	179
Soda	136
Potass	85
Strontian	85
Barytes	56

III. *Muriatic Acid.*

	Intensity.
Ammonia	171
Magnesia	111
Lime	84
Soda	73
Potass	56
Strontian	41
Barytes	31

IV. *Carbonic Acid.*

	Intensity.
Ammonia	unknown
Magnesia	200
Lime	81
Soda	66
Potass	105
Strontian	43
Barytes	28

A Table of the real Specific Gravity of Solutions as indicated by Baumé's Arëometer for Salts.—Drawn up by Robert Bingley, Esq.

Spec. Grav.	Degrees of Arëometer.	Spec. Grav.	Degrees of Arëometer.
1,435	45	1,300	34
1,416	43	1,283	32
1,400	42	1,275	31
1,383	41	1,267	30
1,367	40	1,250	29
1,358	39	1,233	28
1,350	38	1,216	26
1,342	37	1,167	20
1,333	36	1,150	18
1,312	35		

Table of the Boiling Point of sundry Liquids, &c.

Ether - -	98°	Phosphorus -	554°
Aqua ammonia -	140	Oil of turpentine	560
Alcohol - -	176	Sulphur -	570
Water - -	212	Sulphuric acid	546
Muriate of lime -	230	Linseed oil -	600
Nitric acid -	248	Mercury -	660

Table of the Quantity of real Acid taken up by Alkalies and Earths.—By Mr. Kirwan.

100 Parts.	Sulphuric	Nitric.	Muriatic.	Carbonic.
Potass - -	82,48	84,96	56,30	105
Soda - -	127,68	135,71	73,41	66,80
Ammonia -	383,80	247,82	171	Variable
Barytes -	50	56	31,80	282
Strontian -	72,41	85,56	46	43,20
Lime - -	143	179,50	84,49	81,81
Magnesia -	172,64	210	111,35	200
Alumine -	150,90	- -	- -	335

Table of the Quantity of Alkalies and Earths taken up by 100 Parts of real Sulphuric, Nitric, Muriatic, and Carbonic Acids, when saturated.—By Mr. Kirwan.

100 Parts.	Potass.	Soda.	Ammo.	Barytes.	Stron.	Lime.	Magnes
Sulphuric	121,48	78,32	26,05	200	138	70	57,92
Nitric -	117,70	73,03	40,35	178,12	116,86	55,70	47,64
Muriatic	177,60	136,20	58,48	314,46	216,21	118,30	898
Carbonic	95,10	149,60	- -	354,50	231	122	50

A Table of Carats, with their corresponding Degrees of Specific Gravities, for ascertaining the Specific Gravities of Alkaline Leys, or other Fluids, heavier than Water.

Carats.		Sp. Grav.	Carats.		Sp. Grav.
1	=	1.0078	33	=	1.2578
2		1.0156	34		1.2656
3		1.0234	35		1.2734
4		1.0312	36		1.2812
5		1.0390	37		1.2890
6		1.0468	38		1.2968
7		1.0546	39		1.3046
8		1.0625	40		1.3125
9		1.0703	41		1.3203
10		1.0781	42		1.3281
11		1.0859	43		1.3359
12		1.0937	44		1.3437
13		1.1015	45		1.3515
14		1.1093	46		1.3593
15		1.1171	47		1.3671
16		1.1250	48		1.3750
17		1.1328	49		1.3828
18		1.1406	50		1.3906
19		1.1484	51		1.3984
20		1.1562	52		1.4062
21		1.1640	53		1.4140
22		1.1718	54		1.4218
23		1.1796	55		1.4296
24		1.1875	56		1.4375
25		1.1953	57		1.4453
26		1.2031	58		1.4531
27		1.2109	59		1.4609
28		1.2187	60		1.4687
29		1.2265	61		1.4765
30		1.2343	62		1.4843
31		1.2421	63		1.4921
32		1.2500	64		1.5000

(Table continued.)

Carats.		Sp. Grav.	Carats.		Sp. Grav.
65	=	1.5078	97	=	1.7578
66		1.5156	98		1.7656
67		1.5234	99		1.7734
68		1.5312	100		1.7821
69		1.5390	101		1.7890
70		1.5468	102		1.7968
71		1.5546	103		1.8046
72		1.5625	104		1.8124
73		1.5703	105		1.8202
74		1.5781	106		1.8280
75		1.5859	107		1.8358
76		1.5937	108		1.8436
77		1.6015	109		1.8514
78		1.6093	110		1.8593
79		1.6171	111		1.8671
80		1.6250	112		1.8750
81		1.6328	113		1.8828
82		1.6406	114		1.8906
83		1.6484	115		1.8984
84		1.6562	116		1.9062
85		1.6640	117		1.9140
86		1.6718	118		1.9218
87		1.6796	119		1.9296
88		1.6875	120		1.9375
89		1.6953	121		1.9453
90		1.7031	122		1.9531
91		1.7109	123		1.9609
92		1.7187	124		1.9687
93		1.7265	125		1.9765
94		1.7343	126		1.9843
95		1.7421	127		1.9921
96		1.7500	128		2.0000

For an account of the principle on which this table is constructed, see Additional Notes, No. 1.

TABLE OF BAUMÉ'S HYDROMETERS.

Baume's Hydrometer for Vinous Spirits, or other Liquids lighter than Water. Temperature 55° Fahrenheit.

Degrees.	Sp. Grav.	Degrees.	Sp. Grav.	Degrees.	Sp. Grav.
10	= 1.000	21	= —.922	31	= —.861
11	—.990	22	—.915	32	—.856
12	—.985	23	—.909	33	—.852
13	—.977	24	—.903	34	—.847
14	—.970	25	—.897	35	—.842
15	—.963	26	—.892	36	—.837
16	—.955	27	—.886	37	—.832
17	—.949	28	—.880	38	—.827
18	—.942	29	—.874	39	—.822
19	—.935	30	—.867	40	—.817
20	—.928				

Baumé's Hydrometer for Liquids heavier than Water. Temperature 55° Fahrenheit.

Degrees.	Sp. Grav.	Degrees.	Sp. Grav.	Degrees.	Sp. Grav.
0	1.000	27	1.230	51	1.547
3	1.020	30	1.261	54	1.594
6	1.040	33	1.295	57	1.659
9	1.064	36	1.333	60	1.717
12	1.089	39	1.373	63	1.779
15	1.114	42	1.414	66	1.848
18	1.140	45	1.455	69	1.920
21	1 170	48	1.500	72	2.000
24	1.200				

Table of the Degrees of different Thermometers (omitting Fractions) at which some chemical Phænomena occur.

	Fahr.	Reau.	Cent.	Wedg.
Cold produced by Mr. Walker -	— 90	— 54	— 68	
Nitric acid freezes - - -	— 66	— 44	— 55	
Mercury freezes - - - -	— 39	— 32	— 39	
Brandy freezes - - - -	— 7	— 17	— 14	
Cold produced by mixing equal parts of snow and muriate of soda	0	— 14	— 18	
Strong wines freeze - - -	20	— 5.	— 6.	
Water freezes - - - -	32	0	0	
Vinous fermentation begins - -	59	12	15	
Ditto rapid, and acetous begins -	77	20	25	
Acetous fermentation ceases -	88	25	31	
Ether boils - - - -	98	29	36	
Spermaceti melts - - -	112	36	45	
Tallow melts - - - -	127	42	53	
Ammonia separates from water -	130	44	54	
Bees' wax melts - - - -	142	49	61	
Camphor sublimes - - -	145	50	63	
Bleached wax melts - - -	155	55	69	
Sulphur evaporates - - -	170	61	77	
Alcohol boils - - - -	176	64	80	
Water boils - - - -	212	80	100	
Sulphur melts - - : -	234	89	111	
Nitrous acid boils - - -	242	93	116	
Sulphur burns slowly - - -	303	120	150	
Tin melts - - - - -	442	182	227	
Sulphuric acid boils - - -	590	248	310	
Lead melts - - - -	612	258	325	
Mercury boils - - - -	660	279	350	
Zinc melts - - - -	700	297	371	
Iron a bright red in the dark -	750	315	384	
Hydrogen gas burns - - -	800	341	427	
Iron red in the twilight - -	884	380	475	
—— red hot in a common fire -	1050	448	560	
—— red heat in day-light - -	1077	462	577	1
Enamel colours burnt - -	1807	737	986	6
Diamond burns - - -	2897	1451	1814	14
Brass melts - - - -	3807	1678	2100	21
Copper melts - - - -	4587	2024	2530	27
Silver melts - - - -	4717	2082	2602	28
Gold melts - - - -	5237	2318	2780	32
Delft ware fired - - - -	6507	2880	3580	40
Cream-coloured stone ware fired -	12257	5370	6770	86
Flint glass furnace greatest heat -	15897	7025	8750	114
Smith's forge - - - -	17327	7650	9600	125
Cobalt melts—Cast iron melts -	17977	7975	9850	130
Nickel melts - - - -	20577	9131	11414	150
Iron melts - - - -	21637	9602	12001	158
Manganese melts - - - -	21877	9708	12136	160
Platina melts - - - -	23177	10286	12857	170
Greatest heat observed - - -	25127	11100	13900	185

Table of Freezing Mixtures.—From Mr. Walker's Papers in the Philosophical Transactions.

A Mixture of		Reduces the Temperature
Sulphate of soda	8	from 50° to 0°
Muriatic acid	5	
Snow	1	from 32° to 0°
Muriate of soda	1	
Snow	2	from 0° to — 5°
Muriate of soda	1	
Snow	1	from — 5° to — 18°
Muriate of soda	5	
Muriate of ammonia and nitrate of potass, of each	5	
Snow	1	from 20° to — 60°
Diluted sulphuric acid	1	
Snow	1	from — 40° to — 73°
Muriate of lime	3	
Snow	8	from — 68° to — 91°
Diluted sulphuric acid	10	

The salts ought to be fresh crystallized, and reduced to very fine powder, and the mixtures made in thin vessels as quickly as possible.

Numerical Expression of Chemical Affinities.—By M. Morveau.

	Sulphuric Acid.	Nitrous Acid.	Muriatic Acid.	Acetous Acid.	Carbonic Acid.
Barytes	65	62	36	29	14
Potash	62	58	32	26	9
Soda	58	50	28	25	8
Lime	54	44	20	19	12
Ammonia	46	38	14	20	4
Magnesia	50	40	16	17	6
Argil	40	36	10	15	2

Note. The above table, showing the comparative force of attractions between the aforesaid bodies, may be useful to point out the probability of any particular decomposition, previous to the attempt being made.

Table of the component Parts of Salts.—By Mr. Kirwan.

Salts.	Basis.	Acid.	Water.	State.
Pearl ash	60	30	6	Dry
Carbonate of potass	41	43	16	Crystallized
——— soda	21.58	14.42	64	Fully crystallized
——— soda	59.86	40.05	- -	Desiccated
——— barytes	78	22	- -	Natural
——— strontian	69.5	30	- -	Natural
——— lime	55	45	- -	Natural and pure
——— magnesia	25	50	25	Crystallized
——— common do.	45	34	21	Dried at 80°
Sulphate of potass	54.08	45.02	- -	Dry
——— soda	18.48	23.52	58	Fully crystallized
——— soda	44	56	- -	Desiccated at 700°
——— ammonia	14.24	54.66	31.1	
——— barytes	66.66	33.33	- -	Natural
——— strontian	58	42	- -	Natural
——— lime	32	46	22	Dried at 66°
——— lime	35.23	50.39	14.38	Dried at 170°
——— lime	38.81	55.84	5.35	Ignited
——— lime	41	59	- -	Incandescent
——— magnesia	17	29.35	53.65	Fully crystallized
——— magnesia	36.68	63.32	- -	Desiccated
Alum	31.24 & wat. }	17.66	51	Crystallized
Alum	63.75	36.25	- -	Desiccated at 700°
Nitrate of potass	51.8	44	4.2	Dried at 70°
——— soda	40.58	53.21	6.21	Dried at 400°
——— soda	42.34	57.55	- -	Ignited
——— ammonia	23	57	20	
——— barytes	57	32	11	Crystallized
——— strontian	36.21	31.07	32.72	Crystallized
——— lime	32	57.44	10.56	Well dried in air
——— magnesia	22	46	22	Crystallized
Muriate of potass	64	36	- -	Dried at 80°
——— soda	53	47 & wat	- -	Dried at 80°
——— ammonia	- -	- -	- -	Crystallized
——— ammonia	25	42.75	32.25	Sublimed
——— barytes	64	20	16	Crystallized
——— barytes	76.2	23.8	- -	Desiccated
——— strontian	40	18	42	Crystallized
——— strontian	69	31	- -	Desiccated
——— lime	50	42	8	Red hot
——— magnesia	31.07	34.59	34.34	Sensibly dry.

A Table of the Properties of several of the Salts, arranged in each Class according to the Affinities of their Radicals for the Acids.

Salts.	*Origin.*	*Taste.*	*Form of their Crystals.*	*Action of the Air.*	*Action of Heat.*	*Solubilty in 100 Parts of Water.*	
						60°	*Boiling.*
Sulphate of barytes	Native	None		None	Decrepitates	Insoluble	Insoluble
——— potass	Artificial	Bitter and acrid	Six-sided prisms	Ditto	Ditto	6	20
——— ditto super	Ditto	Sharp and hot	Ditto	Little	Fusible	50	100
——— soda	In sea water	Bitter and cool	Ditto grooved	Effloresces	Aqueous fusion	20	45
——— strontian	Native	None	Needles intersecting each other	None	Fusible at a high temperature	Insoluble	Insoluble
——— lime	Ditto	Hardly perceptible	Quadrangular prisms	Ditto	Calcines and melts	Nearly inso.	Nearly insol.
——— ammonia	Artificial		Six-sided prisms	Little	Aqueous fusion	50	50 little more
——— magnesia	In sea water	Bitter and cool	Four-sided ditto, ending in pyramids	Slightly efflorescent	Ditto	100	133
——— ditto and ammonia	Artificial	Ditto and acrid	Octahedrons	None	Ditto	Little solu.	Little soluble
——— alumine super	Ditto	Astringent	Thin pearly crystals	Little	Dries to powder	Moderately	Moderately
——— ditto and potass	Ditto	Ditto and styptic	Octahedrons	Ditto	Melts and dries	5	75
Sulphite of barytes	Ditto	Little	Tetrahedrons	Ditto		Insoluble	Insoluble
——— lime	Ditto	Sulphureous	Six-sided prisms	Effloresces	Dries to powder	$\frac{1}{8}$th of a part	
——— potass	Ditto	Ditto sharp and acrid	Various	Ditto	Decrepitates	100	Still more
——— soda	Ditto	Ditto and cool	Four-sided prisms	Ditto	Watery fusion	25	100
——— ammonia	Ditto	Cool	Six-sided ditto, and various	Deliquesces	Decrepitates	100	
——— magnesia	Ditto	Sweet and earthy	Flat transparent tetrahedrons	Effloresces	Softens and dries	5	
——— alumine	Ditto	Sulphureous and earthy	In white powder	Changes to sulphate	Decomposes	Insoluble	Insoluble

(Table continued.)

Salts.	Origin.	Taste.	Form of their Crystals.	Action of the Air.	Action of Heat.	Solubility in 100 Parts of Water.	
						60°	Boiling.
Nitrate of barytes	Artificial	Hot, acrid, and rough	Octahedrons and plates	Little	Decrepitates	9	30
——— potass	Native	Cool and bitter	Various	None	Melts	14	200
——— soda	Artificial	Ditto	Rhomboidal cubes	Softens	Decrepitates	33	100
——— strontian	Ditto	Cool and penetrating	Octahedrons	None	Ditto	20	
——— lime	Ditto and native	Acrid, hot, and bitter	Six-sided prisms	Deliquesces	Fuses and decomposes	400	Still more
——— ammonia	Artificial	Acrid and bitter	Various	Ditto	Watery fusion	50	200
——— magnesia	From mother waters of nitre	Bitter	Small needles and four-sided prisms	Ditto	Fusible	100	
——— alumine	Artificial	Astringent	Does not crystallize	Ditto	Decomposes	Extremely soluble	
Muriate of barytes	Ditto	Pungent	In tables and octagons	Unalterable	Decrepitates	18	
——— potass	Ditto	Pure saline taste	Cubes	Moistens a little	Ditto	33	
——— soda	Sea and rocks	Ditto	Ditto	Ditto and dries again	Ditto	35	36
——— strontian	Artificial	Pungent	Fine prisms	Unalterable	Melts	120	
——— lime	Mineral waters	Ditto	Needle-like ditto	Very deliquescent	Ditto	200	
——— ammonia	Native	Bitter	Various	None	Fusible and volatile	30	100
——— magnesia	In waters	Ditto and disagreeable	In powder, or jelly	Deliquesces	Ditto and decomposes	100	
Oxygenized muriate of potass	Artificial	Cool and harsh	Square thin plates	None	Ditto and ditto	5	33
Phosphate of barytes	Ditto	Insipid	Heavy powder	Ditto	Fusible in great heat	Insoluble	Insoluble
——— strontian	Ditto	Ditto	White ditto	Ditto	Ditto	Ditto	Ditto
——— lime	Native	Ditto	Various prisms	Ditto	Ditto with difficulty	Ditto	Ditto
——— ditto super	Artificial	Sour	Plates or silky threads	Moistens a little	Softens and dries		
——— soda	Ditto	Mild, saline	Various	Effloresces outwardly	Aqueous fusion	25	50

(Table Continued.)

Salts.	*Origin.*	*Taste.*	*Form of their Crystals.*	*Action of the Air.*	*Action of Heat.*	*Solubility in 100 Parts of Water.*	
						60°	*Boiling.*
Phosphate of ammonia	Artificial	Salt and urinous	Four-sided prisms, ending in pyramids	None	Aqueous fusion	25	50 rather more
——— ditto and soda	In urine			Effloresces			
Phosphite of lime	Artificial	Acid	Small needles	None	Decomposes	Sparingly	
——— barytes	Ditto	Insipid	White powder	Ditto	Melts	Ditto	
——— magnesia	Ditto	Ditto	Flaky crystals	Effloresces	Ditto	¼th of a part	
——— potass	Ditto	Sharp	Four-sided prisms	Little	Decrepitates and melts	33	
——— soda	Ditto	Mild and cool	Irregular ditto	Effloresces	Melts	50	50
——— ammonia	Ditto	Sharp	Needles and prisms	Deliquesces	Ditto and decomposes	50	
Fluate of lime	Native	None	Various	None	Decrepitates	Insoluble	
——— soda	Artificial	Bitter	Cubes	Ditto	Ditto	Difficult	
Borate lime	Ditto and native	Insipid	White powder			Ditto	
——— ditto and magnesia	Native	Ditto	Polyhedron with 22 faces	None	Decrepitates	Insoluble	
——— soda	Ditto	Alkaline and sweet	Irregular	Effloresces	Aqueous fusion	8½	17
Carbonate of barytes	Ditto		Striated masses	None	Fuses	Nearly inso.	
——— strontian	Ditto	None	Striated prisms	Ditto	Ditto and decomposes	Ditto	
——— lime	Ditto	None	Various	Ditto	Decrepitates	Insoluble	
——— potass	Ditto and artificial	Urinous	Square prisms terminated by square pyramids	Crystals effloresce	Aqueous fusion	25	80
——— soda	Native	Ditto	Irregular octahedrons	Ditto much	Ditto	50	100
——— magnesia	Artificial	None	Small prisms	Ditto	Decrepitates	2	If crystallized
——— ammonia	Ditto	Little acrid	Irregular	Unalterable	Sublimes	50	100

EXPERIMENTS.

Nothing tends to imprint chemical facts upon the mind so much as the exhibition of interesting Experiments. With this view the following Selection has been made, in which such experiments as may be performed with ease and *safety*, have uniformly been preferred. The original design of the author was to have explained the cause of each result to the student, and indeed most of the experiments were written with that intention; and the rationale of each was actually drawn up to accompany them. But having since thought that this method might perhaps tend to check that spirit of inquiry which ought to be encouraged in youth, he has determined merely to give the mode of conducting each experiment, and leaves it to the pupil himself to discover the *cause* of every effect; earnestly advising him not to perform a second experiment till he has fully satisfied himself respecting the operation of the former: this he may do by referring to the proper places in the Catechism, or the Notes which are annexed.

No. 1. Take a small phial about half full of cold water; grasp it gently in the left hand, and from another phial pour a little sulphuric acid very gradually into the water. A strong SENSATION OF HEAT will immediately be perceived. This, by the continued addition of the acid, may be increased to many degrees beyond that of boiling water. See pages 92 and 106.

2. Take a small phial, in one hand, containing some pulverized muriate of ammonia; pour a little water upon it, and shake the mixture. In this instance a SENSATION OF COLD will immediately be felt. See page 96.

3. Into a tea-cup, placed upon a hearth, and containing about a table-spoon full of oil of turpentine, pour about half

the quantity of strong nitrous acid, previously mixed with a few drops of sulphuric acid. The moment the acids come in contact with the turpentine, FLAME will be produced. In performing this experiment it is advisable to mix the acids in a phial, to tie the phial to the end of a stick, and, at arm's length, to pour its contents into the oil; as the sudden combustion sometimes occasions a part of the liquids to be thrown out of the vessel. See note, page 94.

4. Put about an ounce of marble grossly pulverized into an eight-ounce phial, with about an equal quantity of water. Pour upon it a little sulphuric acid, and CARBONIC ACID GAS will be evolved*. See page 344.

5. Put about an ounce of iron filings into a phial, with about three or four ounces of water; pour a little sulphuric acid upon the contents, and HYDROGEN GAS will be evolved. See notes, page 130.

6. Fill a glass jar with water, invert it upon the shelf of a pneumatic trough; and having heated a common iron poker red hot, plunge it into the water under the jar. In this case also part of the water will be decomposed, and HYDROGEN GAS will ascend through the water into the upper part of the jar. See page 126.

7. Put some sulphuret of iron into a phial, pour a little diluted sulphuric acid over it, and attach a bladder, prepared as directed for experiment No. 4., to the phial. SULPHURETTED HYDROGEN, a gas extremely fetid and disagreeable, will immediately be evolved; though the ingredients here employed were destitute of smell. See page 307.

8. Put an ounce or two of the black oxide of manganese into a small glass retort, pour a little concentrated sulphuric acid upon it, and apply the heat of a lamp. OXYGEN GAS will be disengaged in abundance. See Additional Notes, No. 7.

9. Into a small glass retort put a mixture of two parts of quick-lime, and one of muriate of ammonia, both in powder. Apply the heat of a lamp, and AMMONIACAL GAS will come over. See page 199.

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* The cheapest receiver for the collection of this and other gases is a moistened bladder, with a piece of tobacco-pipe firmly tied into its neck, and twisted in such a manner as to expel all the common air. This may easily be adapted to any vessel by means of the pipe, which may be fixed in the cork, and closely luted in the usual way.

10. Pour a little sulphuric acid upon a small quantity of quicksilver in a glass retort, apply heat, and SULPHUROUS ACID GAS may be collected. See page 216.

11. Take a few shreds or filings of copper, and pour over them a little diluted nitrous acid, in the proportion of about three parts of water to one of acid. The gas evolved in this case is NITROUS GAS. See page 225.

12. Upon an ounce or two of nitrate of potass in a glass retort pour some sulphuric acid; give it heat by means of a lamp, and collect NITROUS ACID. See page 224.

13. Treat muriate of soda in the same manner with sulphuric acid, and MURIATIC ACID in the gaseous form will rise from the retort. See note †, page 218.

14. Convey some muriatic acid gas into a glass jar containing a portion of the gas produced in experiment 9. From the mixture of these two invisible gases, a SOLID SUBSTANCE will be produced; viz. the common sal ammoniac; this may be perceived to deposit itself upon the sides of the vessel in a neat crystallized form. See pages 201 and 202.

15. Convey some carbonic acid gas into a glass jar containing a portion of ammoniacal gas. The instant the two gases come into contact a great absorption will take place, and SOLID CARBONATE OF AMMONIA will be formed on the inner surface of the jar. See page 200.

16. If common Glaubers salt be dried and reduced to powder, as directed note †, page 288, and then dissolved in three times its weight of boiling water, it will not only be found to crystallize again on cooling, but the crystals will assume the identical forms which they exhibited before they were pulverized. This experiment is designed to show that a DETERMINATE FIGURE has been instamped upon every INDIVIDUAL SALT.

17. Dissolve $\frac{3}{4}$ of an ounce of Glaubers salt in two ounces of boiling water, pour it while hot into a phial and cork it close. In this state it will not crystallize, even when perfectly cold; but if the cork be now removed, the crystallization will be seen to commence and proceed with rapidity; affording an instance of the effect of ATMOSPHERIC AIR on CRYSTALLIZATION. See page 284.

18. Repeat the experiment with a small thermometer immersed in the solution, and closed so as to exclude the atmospheric air. If the solution be suffered to cool completely under

these circumstances, the thermometer will be seen to rise on the removal of the cork. This experiment is designed to show that saline solutions give out CALORIC in the act of CRYSTALLIZATION. See last note of page 96.

19. Put about half an ounce of quicksilver into a wine-glass, and pour about an ounce of diluted nitrous acid upon it. The nitrous acid will be decomposed by the metal with astonishing rapidity; the bulk of the acid will be quickly changed to a beautiful green, while its surface exhibits a dark crimson: and an effervescence indescribably vivid and pleasing will go on during the whole time the acid operates upon the quicksilver. When a part only of the metal is dissolved a change of colour will again take place, and the acid by degrees will become paler, till it is as pellucid as pure water. This is one instance of a METALLIC SOLUTION by means of an ACID; in which the opacity of a metallic body is completely overcome, and the whole rendered perfectly transparent.

20. Take the metallic solution formed in the last experiment, add a little more quicksilver to saturate the acid; then place it at some distance, over the flame of a lamp, so as gently to evaporate a part of the water. The new formed salt will soon be seen to begin to shoot into needle-like prismatic crystals, crossing each other in every possible direction; affording an instance of the formation of a METALLIC SALT.

21. Pour a drachm by weight of strong nitrous acid into a wine-glass, add two drachms of distilled water*, and, when mixed, throw a few very small pieces of granulated tin into it. A violent effervescence will take place, the lighter particles of the tin will be thrown to the top of the acid, and be seen to play up and down in the liquor for a considerable time, till the whole is dissolved. This is another example of a TRANSPARENT LIQUID holding a METAL IN SOLUTION. See page 440.

22. Dissolve one ounce of quicksilver *without* heat in $\frac{3}{4}$ of an ounce of strong nitrous acid, previously diluted with one ounce and a half of water: Dissolve also the same weight of quicksilver, by *means of heat*, in the same quantity of a similar acid, and then to each of these colourless solutions, add a colourless solution of ammonia. In the one case, the metal will be precipitated in a *black*, in the other, in a *white* powder, affording an ex-

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* Where distilled water is not at hand, clean *rain* water will answer nearly as well for most purposes.

ample of the difference of colour of metallic oxides, arising from DIFFERENT DEGREES OF OXIDIZEMENT. See page 430.

23. Take an ounce of a solution of potass, pour upon it half an ounce of sulphuric acid; lay the mixture aside, and when cold, crystals of sulphate of potass will be formed in the liquor. Here a MILD SALT has been formed from a mixture of two *corrosive* substances. See page 179.

24. Take carbonate of ammonia (the common volatile *smelling* salt), and pour upon it muriatic acid so long as any effervescence continues. The produce will be a SOLID SALT, perfectly *inodorous*, and of little taste. See page 201.

25. Take caustic soda one ounce, pour over it one ounce of muriatic acid, both of these corrosive substances. The produce will be our COMMON TABLE SALT. See page 179.

26. Mix in a wine-glass equal quantities of a saturated solution of muriate of lime, and a saturated solution of carbonate of potass, both transparent *fluids:* stir the mixture, and a SOLID MASS will be the product. See page 290.

27. Take the substance produced in the foregoing experiment, and pour a very little nitric acid upon it. The consequence will be, the solid matter will again be taken up, and the whole exhibit the appearance of one homogeneous fluid. An instance of a solid *opake* mass being converted by a chemical agent to a TRANSPARENT LIQUID. See pages 163 and 292.

28. Take a transparent saturated solution of sulphate of magnesia, (Epsom salt,) and pour into it a like solution of caustic potass, or soda. The mixture will immediately become almost SOLID. This instance of the sudden conversion of two fluids to a solid, and that related No. 26, have been called *chemical miracles*. See page 292.

29. Take a portion of dried sulphate of iron, and an equal quantity of nitrate of potass, grind them together in a mortar, and put the whole into a small glass retort. Adapt a receiver to the retort with one or two bottles, according to the plan of Woulfe's apparatus, and apply the heat of an Argand lamp. After some time a gas will be disengaged, which will be condensed by the cold receivers, forming the true *nitrous acid.* We have here a CORROSIVE FLUID produced from the mixture of two *mild and solid* substances. See page 225.

30. Pour a little pure water into a small glass tumbler, and

put one or two small pieces of phosphuret of lime into it. In a short time FLASHES OF FIRE will dart from the surface of the water, and terminate in ringlets of smoke, which will ascend in regular succession. See page 317.

31. Put thirty grains of phosphorus into a Florence flask with three or four ounces of water. Place the vessel over a lamp, and give it a boiling heat. Balls of fire will soon be seen to issue from the water, after the manner of an artificial firework, attended with the most beautiful corruscations. An experiment to show the extreme INFLAMMABILITY OF PHOSPHORUS. See note ||, page 317.

32. Into an eight-ounce retort, pour four ounces of pure water, add a little solution of pure potass, and give it a boiling heat with a lamp. When it boils, drop a small piece of phosphorus into it, and immerse the beak of the retort in a vessel of water. Bubbles of PHOSPHURETTED HYDROGEN GAS will issue from the retort, rise through the water, and take fire the moment they come in contact with atmospheric air, somewhat similar to the appearance mentioned at experiment No. 30. See page 310.

33. Fix a small piece of solid phosphorus in a quill, and write with it upon paper. If the paper be now carried into a dark room, the writing will be BEAUTIFULLY LUMINOUS. See page 317.

34. Pour a little phosphuretted ether upon a lump of sugar, and drop it into a glass of water, a little warm. The surface of the water will soon become luminous; and if it be moved by blowing gently with the mouth, beautiful and brilliant undulations of its surface will be produced, exhibiting the appearance of a LIQUID COMBUSTION.

35. If any part of the body be rubbed with liquid phosphorus, or phosphuretted ether, that part, in a dark room, will appear as though it were ON FIRE, without producing any dangerous effect, or sensation of heat. See page 318.

36. Take about six grains of oxygenized muriate of potass, and three grains of flour sulphur; rub them together in a mortar, and a smart DETONATING NOISE will be produced. Continue to rub the mixture hard, and the reports will be frequently repeated, accompanied with vivid flashes of light. If the same mixture be wrapped in paper, laid on an anvil, and smartly struck with a hammer, the report will be as loud as what is usually produced by a pistol. See page 268.

37. Take ten grains of oxygenized muriate of potass, and

one grain of phosphorus. Treat this mixture as in the last experiment, and very VIOLENT DETONATIONS will be produced. It is advisable *never to exceed* the quantity of phosphorus that is prescribed here, and in other similar experiments.

38. Take a similar quantity of oxygenized muriate of potass with three or four grains of flour sulphur, and mix the ingredients very well on paper. If a little of this mixture be taken up on the point of a knife and dropped into a wine-glass containing some sulphuric acid, a beautiful COLUMN OF FLAME will be perceived, the moment the powder comes in contact with the acid.

39. Put a little oxygenized muriate of potass and a bit of phosphorus into an ale-glass, pour some cold water upon them cautiously, so as not to displace the salt. Now take a small glass tube, and plunge it into some sulphuric acid: then place the thumb upon the upper orifice, and in this state withdraw the tube, which must be instantly immersed in the glass, so that on removing the thumb, the acid may be immediately conveyed upon the ingredients. This experiment is an example of a very singular phænomenon, COMBUSTION UNDER WATER.

40. Proceed in all respects as in the last experiment, and add a morsel of phosphuret of lime. Here, besides the former appearance, we shall have COMBUSTION also on the SURFACE OF THE WATER.

41. Prepare a mixture of equal parts of lump sugar and oxygenized muriate of potass; put a small quantity of this mixture upon a plate or a tile; then dip a fine glass rod, or tobacco-pipe, into a phial of sulphuric acid, so as to convey the smallest quantity of the acid; with this touch the powder, and an immediate BURST OF FLAME will be the consequence.

42. Mix, without much friction, ten grains of oxygenized muriate of potass with one grain of phosphorus, and drop the mixture into concentrated sulphuric acid. This is an instance of DETONATION AND FLAME being produced, by the mixture of a powder with a *cold* liquid. See page 268.

43. Pour boiling water upon a little red cabbage sliced, and when cold decant the clear infusion. Divide the infusion into three wine-glasses. To one add a solution of alum, to the second a little solution of potass, and to the third a few drops of muriatic acid. The liquor in the first glass will assume a purple, the second a bright green, and the third a beau-

tiful crimson. Here is an instance of THREE DIFFERENT COLOURS from the same vegetable infusion, merely by the addition of three *colourless* fluids. See pages 179 and 206.

44. Prepare a little tincture of litmus. Its colour will be a bright blue with a tinge of purple. Put a little of it in a phial, and add a few drops of diluted muriatic acid; its colour will change to a *vivid red.* Add a little solution of potass; the red will now disappear, and the *blue* will be restored. By these means the liquor may be changed alternately from a red to a blue, and from a blue to a red, at pleasure. An instance of the effects of acids and alkalies in CHANGING VEGETABLE COLOURS. See pages 179 and 206.

45. Make an infusion of red roses, violets, or mallow flowers; treat it with solution of potass, and it will become *green;* the addition of diluted muriatic acid will convert it immediately to a *red.* This experiment may be frequently varied as the last, and furnishes an excellent TEST FOR ACIDS AND ALKALIES.

46. Add a drop or two of solution of potass to tincture of turmeric. This will change its original bright *yellow* colour to a dark *brown:* a little colourless diluted acid will restore it. By this tincture we can detect the most minute portion of any ALKALI IN SOLUTION.

47. Into a wine-glass of water put a few drops of prussiate of potass; and a little dilute solution of sulphate of iron into another glass: by pouring these two *colourless* fluids together, a BRIGHT DEEP BLUE COLOUR will be immediately produced, which is the true prussian blue.

48. Put some prussiate of potass into one glass; into another a little nitrate of bismuth. On mixing these COLOURLESS fluids, a YELLOW will be the product.

49. Pour a little prussiate of potass into a glass containing a *colourless* solution of sulphate of copper, and a REDDISH BROWN will be produced, being a true prussiate of copper. See page 379.

50. Prepare a phial with pure water and a little tincture of galls; and another with a weak solution of sulphate of iron; then mix these transparent COLOURLESS fluids together, and they will instantly become BLACK. See page 242.

51. Pour a little tincture of litmus into a wine-glass, and into another some diluted sulphate of indigo; pour these two BLUE fluids together, and the mixture will become perfectly RED. See page 179.

52. Drop as much nitrate of copper into water as will form a colourless solution; then add a little ammonia, equally COLOURLESS, and a BLUE COLOUR will arise from the mixture.

53. Take water holding carbonate of iron in solution, and add some diluted prussiate of potass: PRUSSIAN BLUE will be formed by the mixture. See page 247.

54. Take some of the same water as that used in the last experiment; boil it, and now add prussiate of potass. In this case NO COLOUR will be produced.

55. Take some water impregnated with carbonic acid, and add to it a little BLUE tincture of litmus. The whole will be changed to a RED. See page 179.

56. Take some of the same carbonated water, and boil it. Then add a little tincture of litmus, and the blue colour will experience NO CHANGE.

57. Take some of the black liquid described in experiment 50, add by degrees muriatic acid to it, and the COLOUR WILL BE DISCHARGED. Now drop in a little solution of potass, and the black colour will be RESTORED. Some nicety is requisite in adding the acid and alkali; for if they be given in excess the effects will not be so apparent.

58. Take the blue solution formed by experiment No. 52., add a little sulphuric acid, and the colour will *disappear*; pour in a little solution of caustic ammonia, and the BLUE COLOUR WILL BE RESTORED. Thus may the liquor be alternately changed at pleasure. See pages 179 and 206.

59. Spread a piece of tinfoil, such as is used for coating electrical jars, upon a piece of thick paper; pour a small quantity of strong solution of nitrate of copper upon it. Fold it up quickly, and wrap it round carefully with the paper, more effectually to exclude the atmospheric air. Place it then upon a tile, and in a short time *combustion* will commence, and the TIN WILL INFLAME.

60. Take three parts of nitre, two of potass, and one of sulphur; all of these should be thoroughly dry; then mix them by rubbing them together in a warm mortar: the resulting compound is called *fulminating powder.* If a little of this powder be placed upon a fire-shovel over a hot fire, it gradually blackens, and at last melts. At that instant it EXPLODES WITH A VIOLENT REPORT. *Note, This mixture is not dangerous, like the metallic fulminating powders; none of which should be entrusted in the hands of young people.*

61. Whenever uncombined muriatic, or any volatile acid is suspected to be present in any chemical mixture, it may be detected by ammonia. A single drop of ammonia on a feather, or small slip of paper, and held over the mixture, will immediately render the VAPOUR VISIBLE.

62. Ammonia in solution may in like manner be detected by a single drop of muriatic, or acetic acid, which will produce very evident WHITE FUMES. This is merely the reverse of the former experiment. See note §, page 203.

63. Procure a bladder furnished with a stop-cock, fill it with hydrogen gas, and then adapt a tobacco-pipe to it. By dipping the bowl of the pipe into a lather of soap, and pressing the bladder, soap-bubbles will be formed, filled with hydrogen gas. These bubbles will rise into the atmosphere, as they are formed, and convey a good idea of the principle upon which AIR-BALLOONS are inflated. See page 39.

64. Procure a bladder similar to that described in the last experiment, and charge it with a mixture of oxygen and hydrogen gases. With this apparatus blow up soap-bubbles as before, and touch them with a lighted match. The bubbles as they rise will EXPLODE WITH A SMART NOISE. See note §, page 305.

65. Fill a bladder, similar to that directed for experiment No. 4, with hydrogen gas; apply a lighted match to the end of the tobacco-pipe, and press the bladder gently. A PENCIL OF FLAME, extremely beautiful, will be seen issuing from the pipe, till the whole of the hydrogen gas is consumed. See note ‡, page 130.

66. Place some small phials on the shelf of the pneumatic tub, filled with water, and inverted as usual for receiving gases. Now fill these with mixed *oxygen and hydrogen gases* from the bladder, as described in Experiment 64. A lighted match will cause any one of these to EXPLODE WITH VIOLENCE. When the phials are used, it will be prudent to fold them round with a handkerchief, to prevent any injury being received from the glass, in case of bursting; but if small bladders be employed in place of the phials, this precaution will be unnecessary. See note §, page 305.

67. Pour a little lime-water into a wine-glass, and put some solution of oxalate of ammonia, equally transparent, into another glass. If the two clear liquors be poured together, a white precipitate of OXALATE OF LIME will immediately become visible. See note §, page 239.

68. Pour a little lime-water into a phial, and throw some carbonic acid into it. The carbonic acid will seize the lime, and precipitate it in the state of CARBONATE OF LIME.

69. Take the phial made use of in the last experiment, with its contents, and convey an additional portion of carbonic acid into it. The carbonate of lime will now be RE-DISSOLVED, and the liquor rendered TRANSPARENT. See note ‡, page 163.

70. Take the transparent liquid produced in the last experiment, and give it heat. The earth will now be precipitated in the state of CARBONATE OF LIME, as before.

71. Pour some lime-water into a wine-glass, and a little solution of carbonate of potass into another glass. When these two transparent fluids are thrown together, an abundant precipitate of CARBONATE OF LIME will be the consequence. See page 195.

72. Proceed as in the last experiment, but instead of carbonate of potass, pour a solution of Epsom salt into one of the glasses. When these transparent fluids are poured together, a mixed precipitate, of CARBONATE OF MAGNESIA, and SULPHATE OF LIME, will be produced. See page 171.

73. For another experiment take in the same manner, separately, lime-water, and a solution of alum. The union of these solutions will produce a mixed precipitate of ALUMINE and SULPHATE OF LIME.

74. If a strong solution of caustic potass, and a saturated solution of Epsom salt be mixed, the union of these transparent fluids will produce also an abundant precipitate. But this will consist of MAGNESIA and SULPHATE OF POTASS.

75. To a glass of water, suspected to contain carbonic acid, add a small quantity of any of the other acids. If carbonic acid be present, it will become visible by a SPARKLING APPEARANCE on the sides of the glass and surface of the fluid.

76. Prepare two glasses of pure water, and into one of them drop a single drop of sulphuric acid, and mix it with the water. Pour a little muriate of barytes into the other glass, and no change will be perceived: pour some of the same solution into the first glass, containing the sulphuric acid, and a white precipitate of SULPHATE OF BARYTES will be produced. See note †, page 160.

77. Prepare two glasses of water as before, conduct the experiment in the same way as the last, but instead of muriate

of barytes, use *nitrate of lead*. In this case SULPHATE OF LEAD will be precipitated. See page 171.

78. Prepare two glasses of rain water, and into one of them drop a single drop of sulphuric acid. Pour a little *nitrate of silver* into the other glass, and no change will be perceptible. Pour some of the same solution into the first glass, and a white precipitate of SULPHATE OF SILVER will appear.

79. Prepare two glasses as in the last experiment, and into one of them put a drop or two of *muriatic acid*. Proceed as before, and a precipitate of MURIATE OF SILVER will be produced. See last note of page 361.

80. Take two glasses, as in experiment 78, and into one of them put a drop of sulphuric acid, and a drop or two of muriatic acid: proceed as before with the *nitrate of silver*, and a MIXED precipitate will be produced, consisting of MURIATE OF SILVER, and SULPHATE of SILVER.

81. Take the glass containing the mixed precipitate of the last experiment, and give it, by means of a lamp, the heat of boiling water. The sulphate of silver, if there be a sufficiency of water, will now be re-dissolved, and the muriate of silver will remain separate at the bottom of the vessel. This experiment exhibits a method of SEPARATING these METALLIC SALTS whenever they occur in a state of mixture.

82. Mix one ounce of litharge of lead with one drachm of pulverized muriate of ammonia, and submit the mixture to a red heat in a clean tobacco-pipe. The increase of temperature will separate the ammonia in the form of gas, and the muriatic acid will combine with the lead. When the compound is well melted, pour it into a metallic cup, and you will have a true MURIATE OF LEAD of a bright yellow colour, the brilliancy of which may be much heightened by grinding it as usual with oil. In this state it forms the colour called PATENT YELLOW. See note *, page 286.

83. Take one ounce of red lead, and half a drachm of charcoal in powder, incorporate them well in a mortar, and then fill the bowl of a tobacco-pipe with the mixture. Submit it to an intense heat in a common fire, and, when melted, pour it out upon a slab. The result will be METALLIC LEAD completely revived. See page 442.

84. Take a little *red-lead*, expose it to an intense heat in a crucible, and pour it out when melted. The result will be metallic glass, and will furnish an example of the VITRIFICATION OF METALS.

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85. Pour a little solution of indigo in sulphuric acid into a glass of water, and add about an equal quantity of solution of *carbonate of potass.* If a piece of white cloth be dipped in this mixture, it will come out a BLUE. If a piece of yellow cloth be dipped in, it will become a GREEN, or a red will be converted to a PURPLE. A slip of blue litmus paper immersed in it will immediately become RED.

86. If a little fustic, quercitron bark, or other dye, be boiled in water, the colouring matter will be extracted, and a coloured solution formed. On adding a small quantity of dissolved alum to this decoction, the alumine, or base of the salt, will attract the colouring matter, forming an INSOLUBLE COMPOUND, which in a short time will subside, and may easily be separated. See Additional Notes, No. 11.

87. Boil a little cochineal in water with a grain or two of cream of tartar, (super tartrate of potass) and a dull kind of crimson solution will be formed. By the addition of a few drops of nitro-muriate of tin, the colouring matter will be PRECIPITATED OF A BEAUTIFUL SCARLET. This, and some of the former instances, will give the student a tolerably correct idea of the general processes of dyeing woollen cloths. See note †, page 395.

88. If a few strips of dyed linen cloth, of different colours, be dipped into a phial of oxygenized muriatic acid, the colours will be quickly discharged; for there are few colours that can resist the energetic effect of this acid. This experiment may be considered as a complete example of the process of BLEACHING coloured goods. See note †, page 222.

89. Having found a piece of blue linen cloth, that will bleach in oxygenized muriatic acid, dip the tip of the finger in a solution of *muriate of tin,* and press it while wet with the solution, upon a strip of this cloth. After an interval of a few minutes immerse the cloth in the phial of liquid oxygenized muriatic acid, and when it has remained in it the usual time, it will be found that the spot which was previously wet with muriate of tin has preserved its ORIGINAL COLOUR, while the rest of the cloth has become WHITE. See second note, page 393.

90 Dip a piece of white calico in a strong solution of acetate of iron; dry it by the fire, and lay it aside for three or four days. After this, wash it well in hot water, and then dye it black, by boiling it for ten minutes in a strong decoction of Brazil wood. If the cloth be now dried, any figures printed upon it with a *colourless* solution of muriate of tin, will appear of a BEAU-

TIFUL SCARLET, although the ground will remain a permanent BLACK. See note, page 395.

91. Dissolve 4 drachms of sulphate of iron in one pint of cold water, then add about 6 drachms of lime in powder, and 2 drachms of finely pulverized indigo, stirring the mixture occasionally for 12 or 14 hours. If a piece of white calico be immersed in this solution for a few minutes, it will be dyed GREEN; and by exposure to the atmosphere only for a few seconds, this will be converted to a PERMANENT BLUE. See Additional Notes, No. 52.

92. If a piece of calico be immersed in a solution of sulphate of iron, and, when dry, washed in a weak solution of carbonate of potass, a PERMANENT COLOUR will be produced, viz. the BUFF of the calico printers. See note 390.

93. Boil equal parts of arnotto and common potash in water till the whole are dissolved. This will produce the PALE REDDISH BUFF so much in use, and sold under the name of NANKEEN DYE.

94. If muriate of tin, newly made, be added to a solution of indigo in sulphuric acid, the oxygen of the indigo will be absorbed, and the solution instantly converted to a *green*. It is on the same principle that muriate of tin is employed in cleansing discoloured leather furniture; as it absorbs the oxygen, and the LEATHER IS RESTORED TO ITS NATURAL COLOUR. See note 393.

95. Take a piece of very dark olive-coloured linen that has been dyed with fustic, quercitron bark, or weld, and spot it in several places with a *colourless* solution of muriate of tin. Wherever the cloth has been touched with this solution, the original colour will be discharged, and spots of a BRIGHT YELLOW will appear in its stead.

96. Dip a piece of white calico in a cold solution of sulphate of iron, and suffer it to become entirely dry. Then imprint any figures upon it with a strong solution of colourless citric acid, and allow this also to dry. If the piece be then well washed in pure warm water, and afterwards boiled in a decoction of logwood, the ground will be dyed either of a slate or black colour, according to the strength of the metallic solution, while the printed figures will remain beautifully white. This experiment is designed to show the EFFECT OF ACIDS in DISCHARGING VEGETABLE COLOURS.

97. If lemon juice be dropped upon any kind of buff colour, the dye will be instantly discharged. The application of this

acid by means of the block, is another method by which calico-printers give the WHITE SPOTS or FIGURES to PIECE-GOODS. The crystallized acid in a state of solution is generally used for this purpose. These few experiments will give the student some idea of the nature of calico-printing.

98. Take a slip of blue litmus paper, dip it into acetous acid, and it will immediately become red. This is a test so delicate, that, according to Bergman, it will detect the presence of sulphuric acid, even if the water contain only one part of acid to thirty-five thousand parts of water. Litmus paper which has been thus changed by immersion in acids, is, when dried, a good test for the alkalies; for, if it be dipped in a fluid containing the smallest portion of alkali, the red will disappear, and the paper be restored to its ORIGINAL BLUE COLOUR. See note ‡, page 206.

99. Take a slip of turmeric paper, and dip it into any alkaline solution; this will change the yellow to a deep brown. In many cases turmeric is preferable to litmus paper for detecting alkali in solution, as it suffers no change from carbonate of lime, which is often found in mineral waters. This paper will detect the presence of soda, though it should amount to no more than $\frac{1}{2200}$th part of the water. The paper thus changed by an alkali, would, if dried, be still useful as a test for acids, as these restore its ORIGINAL YELLOW.

100. Write upon paper with a diluted solution of muriate of copper; when dry it will not be visible, but on being warmed before the fire the writing will become of a beautiful YELLOW.

101. Write with a solution of muriate of cobalt, and the writing, while dry, will not be perceptible; but if held towards the fire, it will then gradually become visible; and if the muriate of cobalt be made in the usual way, the letters will appear of an elegant GREEN colour. See page 417.

102. Write with acetate of cobalt, or with a muriate of cobalt, previously purified from the iron which it generally contains. When the writing is become dry, these letters will also be invisible. Warm the paper a little, and the writing will be restored to a beautiful BLUE. See note ||, page 419.

103. Draw a landscape with Indian ink, and paint the foliage of the vegetables with muriate of cobalt, the same as that used in experiment No. 101, and some of the flowers with acetate of cobalt, and others with muriate of copper. While this picture is cold it will appear to be merely an outline of a landscape,

or winter scene; but when gently warmed, the trees and flowers will be DISPLAYED IN THEIR NATURAL COLOURS, which they will preserve only while they continue warm. This may be often repeated. See note 419.

104. Write with dilute nitrate of silver, which when dry will be entirely invisible; hold the paper over a vessel containing sulphate of ammonia, and the writing will appear very distinct. The letters will shine with the METALLIC BRILLIANCY of SILVER. See page 443.

105. Write with a solution of nitrate or acetate of lead. When the writing is dry it will be invisible. Then having prepared a glass decanter with a little sulphuret of iron strewed over the bottom of it, pour a little very dilute sulphuric acid upon the sulphuret, so as not to wet the mouth of the decanter, and suspend the writing by means of the glass stopper, within the decanter. By an attention to the paper the WRITING WILL BECOME VISIBLE by degrees, as the gas rises from the bottom of the vessel. See page 398.

106. Write with a weak solution of sulphate of iron; let it dry, and it will be invisible. By dipping a feather in tincture of galls and drawing the wet feather over the letters, the writing will be RESTORED and appear BLACK. See page 243.

107. Write with a similar solution, and when dry wash the letters in the same way with prussiate of potass, and they will be restored of a BEAUTIFUL BLUE. See note 383.

108. Write with a solution of sulphate of copper, wash as before with prussiate of potass, and the writing will be revived of a REDDISH BROWN colour. See second note, page 379.

109. Procure a glass jar, such as is generally used for deflagrating the gases, and fill it with oxygenized muriatic acid gas. If nickel, arsenic, or bismuth in powder be thrown into this gas, and the temperature of the atmosphere be not lower than 70°, the metal will inflame, and continue to burn with the most BRILLIANT COMBUSTION. See note ‡, page 223.

110. Into a large glass jar, inverted upon a flat brick tile, and containing near its top a branch of fresh rosemary, or any other such shrub, moistened with water, introduce a flat thick piece of heated iron, on which place some gum benzoin in gross powder. The benzoic acid, in consequence of the heat, will be separated, and ascend in white fumes, which will at length condense, and form a most beautiful appearance upon the leaves of the vegetable. This will serve as an example of SUBLIMATION.

111. Introduce a little carbonate of ammonia into a Florence flask and place that part of the flask which contains the salt on the surface of a bason of boiling water: the heat will soon cause the carbonate of ammonia to rise undecomposed, and attach itself to the upper part of the vessel, affording another example of SIMPLE SUBLIMATION. See page 196.

112. Fill a glass tumbler half full of lime-water; then breathe into it frequently *with the mouth open;* at the same time stirring it with a piece of glass. The fluid, which before was perfectly transparent, will presently become quite white, and, if suffered to remain at rest, REAL CHALK will be deposited. See note ‡, page 163.

113. Mix a little acetate of lead with an equal portion of sulphate of zinc; both in fine powder; stir them together with a piece of glass or wood, and no chemical change will be perceptible; but if they be rubbed together in a mortar, the two solids will operate upon each other; an intimate union will take place, and a FLUID WILL BE PRODUCED. If alum or Glauber salt be used instead of sulphate of zinc, the experiment will be equally successful. See pages 292 and 288.

114. If the leaves of a plant, fresh gathered, be placed in the sun as directed page 84, very pure OXYGEN GAS may be collected.

115. Put a little fresh calcined magnesia in a tea-cup upon the hearth, and suddenly pour over it as much concentrated sulphuric acid as will cover the magnesia. In an instant sparks will be thrown out, and the mixture will be COMPLETELY IGNITED.

116. If the student be in possession of an air-pump, the following experiment may be easily performed:—Let him fix a small jar of *ether* within a vessel containing a little water, and place both under the receiver of the air-pump. The exhaustion of the receiver will cause one of the fluids to BOIL, and the other to FREEZE AT THE SAME INSTANT. See last note, page 61.

117. If a few pounds of a mixture of iron filings and sulphur be made into a paste with water, and buried in the ground for a few hours, the water will be decomposed with so much rapidity, that COMBUSTION AND FLAME will be the consequence.

118. Put a little alcohol in a tea-cup, set it on fire, and invert a large bell glass over it. In a short time an aqueous vapour will be seen to condense upon the inside of the bell,

which, by means of a dry sponge, may be collected, and its quantity ascertained. This may be adduced as an example of the formation of WATER BY COMBUSTION. See page 468.

119. Pour a little water into a phial containing about an ounce of olive oil. Shake the phial, and if the contents be observed we shall find that no union has taken place. But if some solution of caustic potass be added, and the phial be then shaken, an intimate combination of the materials will be formed by the disposing affinity of the alkali, and a perfect SOAP produced. See page 190.

120. Put a little common sulphur into an iron dish, place it under a jar of oxygen gas, and set fire to it as directed page 208, and sulphuric acid will be formed. This is an example of the formation of an ACID BY COMBUSTION.

121. Take the acid formed in the last experiment, concentrate it by boiling, mix it with a little powdered charcoal, and submit the mixture in a Florence flask to the heat of an Argand's lamp. By this process sulphur will be regenerated, and will sublime into the neck of the flask. An example of the DECOMPOSITION OF AN ACID. See note *, page 208.

122. Drop upon a clean plate of copper, a small quantity of solution of nitrate of silver; in a short time a metallic vegetation will be perceptible, branching out in very elegant and pleasing forms, furnishing an example of METALLIC REVIVIFICATION. See page 442.

123. Dissolve an ounce of acetate of lead in about a quart or more of water, and filter the solution. If this be put into a glass decanter, and a piece of zinc suspended in it by means of a brass wire; a decomposition of the salt will immediately commence, the lead will be set at liberty, and will attach itself to the remaining zinc, forming a METALLIC TREE. See page 436.

124. Place a phial of water, enclosing a thermometer, in a frigorific mixture, and by avoiding agitation cool it some degrees below the freezing point. If it be now agitated, it immediately becomes solid, and its temperature instantly rises to 32°; an instance of a change of form occasioning an EXTRICATION OF CALORIC.

125. Fill a small glass matrass, or flask, holding about half a pint, with any kind of coloured water, having previously put in a few tea-spoonfuls of *ether:* then invert the flask in a shallow vessel of water, and by degrees pour boiling water upon

its bulb. By the sudden accession of heat the ether will be changed into vapour; which will force out the coloured water, and fill the whole of the vessel. This experiment will afford an example of a liquid being converted into an ELASTIC VAPOUR BY CALORIC. See note ‡, page 109.

126. For want of a proper glass vessel, a table spoonful of ether may be put into a moistened bladder, and the neck of the bladder closely tied. If hot water be then poured upon it, the ETHER WILL EXPAND, and the bladder become inflated. See page 110.

127. Put a small piece of phosphorus into a crucible, cover it closely with common chalk, so as to fill the crucible. Let another crucible be inverted upon it, and both subjected to the fire. When the whole has become perfectly red hot, remove them from the fire, and when cold, the carbonic acid of the chalk will have been decomposed, and the BLACK CHARCOAL, the basis of the acid, may be easily perceived amongst the materials. See second note, page 339.

128. Place a lighted wax taper within a narrow glass jar, then take a jar or phial of carbonic acid gas, and cautiously pour it into the jar containing the taper. This being an *invisible* gas, the operator will appear to invert merely an *empty* vessel, though the taper will be as effectually and instantaneously EXTINGUISHED as if water itself had been used. See page 340.

129. Make a little charcoal perfectly dry, pulverize it very fine, and put it into a warm tea-cup. If some strong nitrous acid be now poured upon it, COMBUSTION AND INFLAMMATION will immediately ensue. See page 322.

130. If strong nitrous acid be poured upon a small quantity of a mixture of oxygenized muriate of potass and phosphorus, FLASHES OF FIRE will be emitted at intervals for a considerable time. See page 268.

131. Put a bit of phosphorus into a small phial, then fill it one-third with boiling olive oil, and cork it close. Whenever the stopper is taken out in the night, LIGHT WILL BE EVOLVED sufficient to show the hour upon a watch.

132. Let sulphuric acid be poured into a saucer upon some acetate of potass. Into another saucer put a mixture of about two parts quick-lime, and one of sal ammoniac, both in powder, adding to these a *very small* quantity of boiling water. Both saucers while separate will yield *invisible* gases; but the moment they are brought close together, the operator will be

ENVELOPED IN VERY VISIBLE VAPOURS. Muriate of soda, in this experiment, may be substituted for acetate of potass. See note §, page 203.

133. Take a glass tube with a bulb in form of a common thermometer; fill it with cold water, and suspend it by a string. If the bulb be frequently and continually moistened with pure sulphuric ether, the water will presently be FROZEN, EVEN IN SUMMER. See note page 122.

134. Dissolve five drachms of muriate of ammonia and five drachms of nitre, both finely powdered, in two ounces of water. A thermometer immersed in the solution will show that the temperature is reduced below 32°. If a thermometer tube, filled with water, be now suspended within it, the WATER will soon be AS EFFECTUALLY FROZEN as in the last experiment. See last note, page 92.

135. Procure a phial with a glass stopper accurately ground into it; introduce a few copper filings, then entirely fill it with liquid ammonia, and stop the phial so as to exclude all atmospheric air. If left in this state no solution of the copper will be effected. But if the bottle be afterwards left open for some time, and then stopped, the metal will dissolve, and the solution will be colourless. Let the stopper be now taken out, and the fluid will become blue, beginning at the surface, and spreading gradually through the whole. If this blue solution has not been too long exposed to the air, and fresh copper filings be put in, again stopping the bottle, the fluid will once more be deprived of its COLOUR, which it will RECOVER ONLY BY THE RE-ADMISSION OF AIR. These effects may thus be repeatedly produced. See note, page 438.

136. Pour concentrated nitric acid upon pieces of iron, and very little action will be seen: but if a few drops of *water* be added a most violent effervescence will immediately commence; the acid will be decomposed with rapidity, clouds of red nitrous gas will be evolved in abundance, and a perfect SOLUTION OF THE METAL effected. See note, page 438.

137. Take any solution of iron, a chalybeate water for instance, and add a little succinate of ammonia; a precipitate will be immediately visible, being succinate of iron. By this test the QUANTITY of iron in any solution may be ACCURATELY ASCERTAINED. See page 292.

138. In like manner add sulphuretted hydrogen to a solution of lead, and a deep brown precipitate will be occasioned. This

is an effectual mode of DETECTING this and some other PERNICIOUS METALS. See Add. Notes, No. 31.

139. Melt sulphur in a small iron ladle, and carry it into a dark room in the state of fusion. If an ounce or two of copper filings be now thrown in, LIGHT WILL BE EVOLVED. See page 461.

140. Dissolve some quicksilver in nitrous acid, and drop a little of the solution upon a bright piece of copper. If it be then gently rubbed with a bit of cloth, the mercury will precipitate itself upon the copper, which will be completely silvered. This experiment is illustrative of the PRECIPITATION OF ONE METAL BY ANOTHER. See page 442

141. If a little nitro-muriate of gold be added to a fresh solution of muriate of tin, both being much diluted with water, the gold will be precipitated of a purple colour, forming that beautiful pigment called POWDER OF CASSIUS. See note †, page 360.

142. Take a phial with solution of sulphate of zinc, and another containing a little liquid ammonia, both transparent fluids. By mixing them, a curious phænomenon may be perceived:—the zinc will be immediately precipitated in a white mass, and, if then shaken, almost as INSTANTLY RE-DISSOLVED.

143. If a colourless solution of galls be added to a solution of bismuth in nitric acid, equally colourless, a *brown* precipitate will be produced. This is a distinguishing CHARACTERISTIC OF THIS METAL. See note †, page 410.

144. If a colourless solution of arsenic in nitric acid be poured into a colourless solution of copper, a *green* precipitate will be produced, forming an arseniate of copper similar to an ore found in the Cornish mines. These metals may be thus RECIPROCALLY DETECTED. See note *, page 378.

145. If a spoonful of good alcohol and a little boracic acid be stirred together in a tea-cup, and then set on fire, they will produce a very beautiful GREEN FLAME. See note †, page 234.

146. If alcohol be inflamed in like manner with a little pure strontian in powder, or any of its salts, the mixture will give a PURPLE FLAME. See note ‡, page 162.

147. If barytes be used instead of strontian, we shall have a brilliant YELLOW FLAME. See page 160.

148. Alloy a piece of silver with a portion of lead, place the alloy upon a piece of charcoal, attach a blow-pipe to a gaso-

meter charged with oxygen gas, light the charcoal first with a bit of paper, and keep up the heat by pressing upon the machine. When the metals get into complete fusion, the lead will begin to burn, and very soon will be all dissipated in a white smoke, leaving the silver in a state of purity. This experiment is designed to show the FIXITY of the NOBLE METALS. See note §, page 399.

149. Fuse a small quantity of nitre in a crucible, and, when in complete fusion, throw pulverized coal into it, by small quantities at a time. The carbonaceous matter will decompose the nitre, and the bituminous part will burn away without acting upon it. This experiment will exhibit a mode of ANALYSING COAL; for every 100 grains of nitre that are decomposed in this way, denote ten grains of carbon. See page 270.

150. Burn a piece of iron wire in a deflagrating jar of oxygen gas, as directed page 453, and suffer it to burn till it goes out of itself. If a lighted wax taper be now let down into the gas this will burn in it for some time, and then become extinguished. If ignited sulphur be now introduced, this will also burn for a limited time. Lastly, introduce a morsel of phosphorus, and combustion will also follow in like manner. These experiments show the RELATIVE COMBUSTIBILITY of different substances. See chapter 12.

151. If oxide of cobalt be dissolved in ammonia, a RED SOLUTION will be produced, different in colour from that of all other metallic oxides. See page 417.

152. If nickel be dissolved in nitric acid, a beautiful GREEN SOLUTION will be formed. The oxide of this metal is used to give a delicate grass green to porcelain. See page 402.

153. When colourless prussiate of potass is added to a solution of titanium, this metal will be precipitated also of a GREEN COLOUR.

154. Add a little colourless solution of galls to a clear solution of antimony in nitro-muriatic acid, and the metal will be precipitated of a PALE YELLOW COLOUR. See page 409.

155. If a solution of tungstate of potass be poured into a solution of the green sulphate of iron, a YELLOW PRECIPITATE will fall down. By this experiment the distinguishing characteristic of this metal is exhibited.

156. Add a few grains of oxygenized muriate of potass to a tea-spoonful or two of alcohol, drop one or two drops of sul-

phuric acid upon the mixture, and the whole will BURST INTO FLAME, forming a very beautiful appearance. See page 268.

157. A mixture of oxygenized muriate of potass and arsenic furnishes a detonating compound, which takes fire with the utmost rapidity. The salt and metal, first separately powdered, may be mixed by the gentlest possible triture, or rather by stirring them together on paper with the point of a knife. If two long trains be laid on a table, the one of gunpowder and the other of this mixture, and they be in contact with each other at one end, so that they may be fired at once; the arsenical mixture burns with the RAPIDITY OF LIGHTNING, while the other burns with comparatively extreme SLOWNESS. See page 268.

158. Into an ale glass of water put a few filings of zinc, and a small bit of phosphorus; then drop a little sulphuric acid upon the mixture by means of a glass tube, as described at No. 39, and phosphuretted hydrogen will presently be disengaged, which will INFLAME on rising to the SURFACE OF THE WATER. See page 310.

159. Take a small piece of phosphuret of lime, a little moistened by the air, and let a single drop of concentrated muriatic acid fall upon it. In this case phosphuretted hydrogen will also be evolved, accompanied by SMALL BALLS OF FIRE darting from the mixture, and the most intolerable fetid smell that can be conceived. See page 310.

160. If 20 grains of phosphorus, cut very small, and mixed with 40 grains of finely granulated zinc, be put into 4 drachms of water, and 2 drachms of concentrated sulphuric acid be added thereto, bubbles of inflamed phosphuretted hydrogen gas will quickly cover the whole surface of the fluid in succession, forming a real AQUEOUS FOUNTAIN OF FIRE. See page 316.

161. If any light substance capable of conducting heat, be placed upon the surface of boiling water, and a bit of phosphorus be laid upon it, the heat of the water will be sufficient to set the PHOSPHORUS ON FIRE. See page 317.

162. If hot water be poured into a glass jar of cold water, it will remain on the *surface*; but if cold water be poured upon hot water, it will sink to the *bottom* of the vessel. This experiment may be rendered more obvious by colouring that portion of the water which is poured in. The design of this is to show the CHANGE of the SPECIFIC GRAVITY of the *same* body, merely by the AGENCY of CALORIC.

163. If a solution of the green sulphate of iron be dropped into a nitro-muriate of gold, the last metal will be immediately precipitated. In this state it is often employed in GILDING CHINA. See page 360.

164. If flowers, or any other figures, be drawn upon a ribband or silk with a solution of nitrate of silver, and the silk, moistened with water, be then exposed to the action of hydrogen gas, the silver will be revived, and the figures, firmly fixed upon the silk, will become visible, and shine with METALLIC BRILLIANCY. See page 443.

165. By proceeding in the same manner, and using a solution of gold in nitro-muriatic acid, silks may be PERMANENTLY GILT at a most insignificant expense, and will exhibit an appearance the most beautiful that can be conceived. See page 443.

166. To a similar solution of gold add about a fourth part of ether; shake them together, and wait till the fluids separate: the upper stratum, or ethereal gold, is then to be carefully poured off into another vessel. If any polished steel instrument or utensil be dipped into this solution, and instantly plunged into water, the surface will have acquired a coat of pure gold, being a very elegant and œconomical mode of PRESERVING POLISHED STEEL FROM RUST. See note 355.

167. If nitro-muriate of platina be mixed with a fourth part of its bulk of ether, and the mixture suffered to settle, the ethereal solution of platina may be decanted as in the preceding experiment. Polished brass, and some other metals immersed in this solution, will be COVERED WITH A COAT OF PLATINA. This process may be applied to many useful purposes. See page 368.

168. If a small thermometer be placed in a glass vessel containing about an ounce of a solution of soda; on adding a sufficient quantity of muriatic acid to saturate the soda, the mercury in the thermometer will expand; affording an instance of HEAT being produced by THE FORMATION OF A SALT. See page 97.

169. Let the last experiment be repeated, with the *carbonate* of soda, instead of pure soda; the mercury will now sink in the thermometer. Here, though the SAME KIND OF SALT is formed, COLD IS PRODUCED. See note †, page 110.

170. Fill a thermometer tube with tepid water, and immerse it in a glass vessel of water of the same temperature, containing a mercurial thermometer. If the whole be now placed in

a bed of snow, or in a frigorific mixture, the water in the tube will suffer a progressive diminution of volume, until it arrives at about 40°; it will then begin to expand gradually, until it becomes solid. This shows how ICE is enabled to SWIM ON THE SURFACE OF WATER. See page 117.

171. Another example on this subject may be shown. Fill a thermometer tube with cold water, at about 32°, and immerse it in a vessel of warm water. In this case, the water in the tube will contract in volume till it arrives at about 42°, when it will appear for a time nearly stationary. If the heat be now continued, the effect will be reversed, for the water in the tube will *expand* as its temperature is increased. This is a curious instance of a CHEMICAL ANOMALY. See note *, page 118.

172. It is an interesting experiment to place a glow-worm within a jar of oxygen gas, in a dark room. The insect will shine with much greater brilliancy than it does in atmospheric air, and appear more alert. As the luminous appearance depends on the will of the animal, this experiment probably affords an instance of the STIMULUS which this gas communicates to THE ANIMAL SYSTEM. See Additional Note, No. 6.

173. Prepare a very dilute and colourless solution of platina by dropping a small quantity of the nitro-muriate of that metal into a glass of water. If a single drop of the solution of muriate of tin be added to this, a bright red precipitate will be instantly produced. A more DELICATE TEST than this of any metal, cannot be conceived. See page 367.

174. If a morsel of dry nitrate of silver (lunar caustic) be laid on a piece of burning charcoal, the metallic salt will immediately deflagrate, throw out the most beautiful scintillations that can be imagined, and the surface of the CHARCOAL will be richly COATED WITH METALLIC SILVER. See page 442.

175. To a colourless solution of nitrate of mercury, add an equally colourless solution of sub-borate of soda. This will produce a double decomposition, and form a bright yellow precipitate of borate of mercury; giving an instance of DIFFERENCE OF COLOUR IN METALS, by their union WITH DIFFERENT ACIDS. See page 430.

176. Into a diluted solution of sulphate of copper, pour a little liquid caustic ammonia. This will precipitate the copper of a bluejsh white. During its examination, however, the

precipitate will be re-dissolved, and a beautiful blue liquid, called AQUA CELESTIS, will be the result. See page 377.

177. If one grain of dry nitrate of bismuth be previously mixed with a grain of phosphorus, and then rubbed together in a metallic mortar, a LOUD DETONATION will be produced. See Additional Notes, No. 22.

178. Write on paper with a solution of nitrate of bismuth; when this is dry the writing will be invisible; but if the paper be immersed in water, it will be DISTINCTLY LEGIBLE. See note *, page 412.

179. A letter written with a diluted solution of bismuth, becomes, when dry, illegible; but a feather dipped in a solution of sulphate of potass, will instantly blacken the oxide, and REVIVE THE WRITING. See note §, page 411.

180. Drop a piece of phosphorus about the size of a pea into a tumbler of hot water, and from a bladder, furnished with a stop cock, force a stream of oxygen gas directly upon it. This will afford the most BRILLIANT COMBUSTION UNDER WATER that can be imagined. See page 317.

181. Paste a slip of litmus paper within a glass jar, near the bottom, then fill the jar with water, and invert it on the shelf of a pneumatic trough. If as much nitrous gas, previously well washed, be passed into the jar as will displace the water below the level of the paper, the colour of the litmus paper will still remain unaltered; but on passing up atmospheric air it will immediately be reddened; showing THE FORMATION OF AN ACID, by the MIXTURE OF TWO GASES. See page 448.

182. Take a few grains of citric acid, and twice as much dry carbonate of potass, or of soda, both in powder; mix them, and put them into a dry glass. No chemical change will take place in either of these salts, but the moment water is poured upon them, an effervescence will ensue; affording an instance of the necessity of WATER to promote SOME CHEMICAL DECOMPOSITIONS.

183. Dissolve a few crystals of nitro-muriate of gold in about 8 times their weight of pure water; place a thin slip of charcoal in the solution, and heat the whole by means of a sand-bath. When the solution has acquired nearly a boiling heat, the gold will precipitate itself on the charcoal, in its metallic splendour, forming a singular and beautiful appearance. This experiment is designed to show that METALS become INSO-

LUBLE, the moment they IMPART THEIR OXYGEN to foreign bodies. See page 357.

184. Proceed as in the last experiment, and submit the vessel with its contents to the rays of the sun. Here the metal will be reduced, and the charcoal as effectually gilt as before. This is illustrative of the DEOXIDIZING POWER OF THE SUN'S RAYS. See note, page 443.

185. Drop a little leaf gold into nitro-muriatic acid, and it will instantly disappear. This experiment is designed to show the great SOLUBILITY OF THE METALS, when submitted to a proper menstruum. See page 358.

186. Pour a little purified nitric acid into one wine-glass, and muriatic acid into another; and drop a little leaf gold into each. Here neither of these corrosive acids will act at all upon the metal, THE GOLD WILL REMAIN UNTOUCHED. Now pour the whole contents of the two glasses together, and the metal will disappear, and be as effectually dissolved as in the last experiment. See note *, page 358.

187. If a little metallic arsenic in powder be mixed with a few zinc filings, and then treated with diluted sulphuric acid, ARSENIATED HYDROGEN GAS may be collected, which burns with a peculiar kind of lambent white flame.

188. If a portion of this gas, issuing from a very small tube, be set on fire, and then immersed in a large glass receiver of oxygen gas, and the stream of arseniated hydrogen kept up by the pressure of the bladder, a BLUE FLAME of uncommon splendour will be produced. See note *, page 414.

189. Take an amalgam of lead and mercury, and another amalgam of bismuth, let these two SOLID AMALGAMS be mixed by triture, and they will INSTANTLY BECOME FLUID. See page 105, and note *, 106.

190. Charge a small glass retort with strong muriatic acid, and insert its beak into a tubulated receiver, containing a little water; then into this receiver insert two small thermometers, the one immersed in the water, the other suspended above it. By applying the heat of a lamp to the retort, muriatic acid gas will be disengaged in abundance; and if the thermometers be examined, that which is suspended in the gas, will be found to have risen only a FEW DEGREES, while that which was immersed in the cold water, has acquired a BOILING HEAT. See page 97.

191. Put into a wine-glass about a scruple of the oxidized-manganese and potass, prepared as directed page 422, and an equal quantity of the same compound into another glass. On one pour hot, and on the other cold water. The HOT SOLUTION will exhibit a BEAUTIFUL GREEN colour; the COLD ONE, a DEEP PURPLE.

192. If a small portion of the same compound be put into several glasses, and water at different temperatures be poured upon each, the contents of each glass will exhibit a different shade of colour. This experiment affords another instance of METALS PRODUCING VARIOUS COLOURS according to their different states of OXIDIZEMENT. For the means of varying this experiment. See note *, page 422.

193. Into a glass of water containing a small portion of common salt, drop some of a clear solution of nitrate of silver, and an insoluble precipitate of muriate of silver will be produced. This experiment is designed to give the pupil some idea of the method of ANALYSING MINERAL WATERS. Every 100 grains of this precipitate, when dried, indicate 42 grains of common salt. See page 361.

194. Into a glass of Aix-la-Chapelle water, or water holding a small portion of potass, drop a little of the solution of nitro-muriate of platina, and an immediate yellow precipitate will be produced. This affords another instance of the nature of the means usually employed to DETECT whatever SUBSTANCES may be DISSOLVED IN MINERAL WATERS. See note *, page 188.

195. Into distilled water drop a little spiritous solution of soap, and no chemical effect will be perceived; but if some of the same solution be added to hard-water, a milkiness will immediately be produced, more or less, according to the degree of its impurity. This is a good method of ASCERTAINING THE PURITY OF SPRING WATER. See note †, page 294.

196. If a little pure WHITE calomel be rubbed in a glass mortar with a little colourless solution of caustic ammonia, the whole will become INTENSELY BLACK.

197. A little of the solution of sulphate of manganese, being exposed in a glass phial to the light of the sun, its rose colour will be entirely destroyed. This is another experiment to show the DE-OXIDIZING POWER OF THE SUN'S RAYS. If the phial be removed into a dark room, the origi-

nal COLOUR of the solution will be RESTORED. See note §, page 443.

198. Dissolve about a drachm of pulverized sulphate of copper in a little boiling water, and an equal quantity of powdered muriate of ammonia in a separate vessel, in hot water. By mixing the contents of the two glasses, a quadruple salt will be formed which gives a YELLOW colour to the solution WHILE HOT, and becomes GREEN WHEN COLD.

199. Mix three grains of sulphur with nine grains of dry nitrate of silver, and lay the mixture in a small heap on an anvil, or on any piece of solid metal. If the mixture be now struck smartly with a *cold* hammer, the sulphur will inflame, but no detonation will ensue. This is an instance of a METALLIC SALT being decomposed and a combustible substance INFLAMED BY PERCUSSION.

200. If the experiment be repeated, and the mass be struck with a *hot* hammer, THE MIXTURE DETONATES, and the SILVER IS REDUCED.

201. Pour a solution of nitrate of silver into a glass vessel, and immerse a few slips of copper in it. In a short time a portion of the copper will be dissolved, and all the silver precipitated in a metallic form. If the solution, which now contains copper, be decanted into another glass, and pieces of iron added to it, this metal will then be dissolved, and the copper precipitated, yielding an example of PECULIAR AFFINITIES. See note *, page 442.

202. Melt a portion of grain tin and pour it into a metallic cup. Allow it to cool till it is congealed to some depth, then pierce the solid crust, and carefully pour out that portion that is still liquid. If what remains in the vessel be suffered to cool entirely, it will present RHOMBOIDAL CRYSTALS of considerable size, formed by the assemblage of a great number of small needles longitudinally united. See note †, page 286.

203. Treat silver in the same way, and we shall procure a metallic mass, crystallized in QUADRANGULAR OR OCTAHEDRAL PRISMS. *These two experiments will succeed better if the metal be poured into a vessel with an orifice in the bottom, which must be stopped with a proper plug, and this removed as soon as the upper crust hardens; the liquid metal will then run out, and that which is congealed will exhibit a regular crystallization.*

204. Form an amalgam with four parts of silver leaf and two of mercury, and dissolve this amalgam in diluted nitric acid. Then

add water to the solution, equal to 30 times the weight of the metals employed, and put the whole aside for use. If an ounce of this solution be at any time poured into a phial, and a small piece of soft amalgam of silver be dropt in, filaments of reduced silver will shoot from it, and extend upwards, in the form of a shrub. This appearance of arborescence is called THE TREE OF DIANA. See page 436.

205. If two parts of sulphate of copper, and three of carbonate of ammonia, (the one a blue, the other a white salt,) be rubbed together in a glass mortar till the carbonic acid be expelled, the mass will become soft and humid, and, when dried, forms a crystalline powder of a DEEP VIOLET colour. This compound was formerly called CUPRUM AMMONIACUM.

206. If a flat bar of iron be hammered briskly on an anvil, its temperature will soon be so increased, that a piece of phosphorus laid upon it, would instantly be inflamed. This experiment is designed to show that CALORIC may be EVOLVED merely BY PERCUSSION; and that, when evolved, it is as active and energetic as though it had never been latent. See page 90.

207. If a little colourless and recently prepared muriate of tin be poured into a rich GREEN solution of muriate of copper, the copper will be deprived of a portion of its oxygen, and a WHITE MURIATE PRECIPITATED. See note, page 393.

208. Into the phial containing the white muriate of the last experiment, pour a little muriatic acid. The precipitate will quickly be dissolved, and THE SOLUTION WILL BE COLOURLESS. See note *, page 438.

209. Procure some solution of sulphate of iron at the *minimum* of oxidizement, by digesting iron filings with the common sulphate. Into this, when filtered, drop a little of the solution of prussiate of potass, and a WHITE PRUSSIATE OF IRON will be precipitated. See note ‡, page 430.

210. If a very little colourless nitric acid be added to a solution of sulphate of iron prepared as in the last experiment, the addition of the prussiate of potass will produce not the white, but the BLUE PRUSSIATE OF IRON. See page 429, and note *, page 438.

211. Pour some pure nitric acid on the black oxide of manganese, and no solution will be effected. But if a little sugar be added, the SUGAR will ABSTRACT a part of the OXY-

GEN from the oxide of manganese, and the acid will then be enabled to dissolve the metal. See note *, page 440.

212. Expose an ounce of nitric acid for an hour, in an open phial, to the direct rays of the sun, and pour another ounce of the same acid, that has not been so exposed, into another phial. If a little of the black oxide of manganese be now put into each, the oxide in the *first phial* will be DISSOLVED, while that in *the other* will NOT BE AFFECTED by the acid. See page 225.

213. If a piece of bright silver be dipped in a solution of sulphate of copper, it will come out unchanged: but if the blade of a clean penknife, or any piece of *polished* iron, be dipped in the same solution, the IRON will instantly put on the APPEARANCE OF COPPER. See page 378.

214. Take the piece of silver, employed in the last experiment, hold it in *contact with the iron*, and then, in this situation, dip them into the same solution, and BOTH will be COVERED WITH COPPER.

215. Dissolve some oxide of nickel in caustic ammonia, which will produce a solution of a rich BLUE colour. By exposure to the air this gradually changes to a PURPLE, and lastly to a VIOLET. The addition of an acid will, however, convert the whole to a GREEN.

216. Take the GREEN solution of the last experiment, and pour caustic ammonia upon it. The original BLUE colour will now be reproduced.

217. Prepare a colourless solution of tartrate of potass and antimony (the common emetic tartar) and pour into it a little liquid sulphuretted hydrogen. This will combine with the metallic oxide, and form an ORANGE-COLOURED precipitate.

218. Melt together equal parts of copper and antimony, the one a yellow, the other a white metal, and the alloy that results from this mixture will take the COLOUR OF THE VIOLET.

219. If the gray sulphuretted oxide of antimony be fused in a crucible, we procure a beautiful transparent glass, which is called the *glass of antimony*. THIS TAKES THE COLOUR OF THE HYACINTH.

220. When antimony is heated to whiteness in a crucible, and in this state agitated, in contact with the air, it inflames

with a sort of explosion, and presents while burning a very singular kind of WHITE FLAME, forming what have been formerly called *argentine flowers.*

221. When antimony is well fused upon charcoal, and if, at the moment when its surface is not covered with any particle of oxide, we throw it suddenly upon the ground, the globules, into which it divides in its fall, BURN with a very LIVELY FLAME, throwing out on all sides BRILLIANT SPARKS, different from that of any other metal.

222. Mix five or six grains of sulphuret of antimony with half its weight of oxygenized muriate of potass, and then, if a sudden stroke be given to the mixture, upon a steel-anvil, it fulminates with a loud report, emitting, according to Fourcroy, a FLAME as brilliant and RAPID AS LIGHTNING.

223. If alcohol contains muriate of magnesia, it has the property of burning with a REDDISH YELLOW FLAME.

224. Evaporate to dryness a solution of gold, made with nitro-muriatic acid, and dissolve the crystals in a sufficiency of pure water to prevent the crystallization of the metallic salt. Thoroughly moisten a little magnesia with this aqueous solution, and place the mixture in the sun's rays. A change of colour will soon be apparent. It will first take a FAINT VIOLET hue, and in a few hours the whole will have acquired a very DEEP PURPLE. See page 443.

225. Moisten a little magnesia with some of the solution as before, and then dry the mixture in the *dark.* If it be then submitted to the action of the sun's rays, it will acquire only a FAINT VIOLET, even BY SEVERAL HOURS exposure. See note, page 438.

226. If the mixture employed in the last experiment be now thoroughly *wetted* with pure water, and again placed within the rays of the sun, its colour will RAPIDLY CHANGE, and will acquire a DEEP PURPLE approaching to CRIMSON. See page 438.

227. Moisten a piece of white riband with the aqueous solution of gold, described at No. 224, and dry it thoroughly in the dark: then suspend it in a clean, dry, transparent phial, and cork it close with a dry cork. Expose the riband, thus secured, to the strong light of a bright sun, for half an hour, and only a FAINT appearance of CHANGE OF COLOUR will be perceived.

228. Take the riband out of the phial that was employed in

the last experiment and *wet* it well with distilled water. If it be now exposed to the sun's rays, it will instantly CHANGE colour, and will quickly be stained of an INDELIBLE PURPLE.

229. Dissolve dry nitrate of silver in pure water; add a little oil of turpentine, shake the mixture, and cork it close. Submit the phial with its contents to the heat of boiling water for an hour, when the metal will be revived, and the inside of the phial, where the oil reposed on the aqueous solution, will be beautifully SILVERED, the revived metal forming a METALLIC RING, extending quite round the phial. See page 442.

230. Immerse a slip of white silk in a solution of nitro-muriate of gold in distilled water, and dry it in the air. Silk thus prepared will not be altered by hydrogen gas; but if another piece of silk be dipped in the solution and exposed while *wet* to the same current of hydrogen gas, instant signs of metallic reduction will appear; the colour will change from yellow to green, and a brilliant film of REDUCED GOLD will soon glitter on its SURFACE.

231. If a piece of silk be immersed in a solution of nitrate of silver and dried in a dark place, and then submitted to hydrogen gas, the silver will not be reduced; but if exposed while *wet* to a stream of the same gas, the surface will quickly be coated with reduced silver; various colours, such as blue, purple, red, orange, and yellow, will accompany the reduction, and the THREADS of the SILK will look like SILVER WIRE. *During these experiments the silk should be constantly kept wet with distilled water.*

232. Dissolve some crystals of muriate of tin in distilled water, then dip a piece of white silk in the solution, and dry it in the air. If this be now immersed in hydrogen gas, no change will be observed; but if it be exposed while *wet* to the same current of gas, the reduction will soon commence, attended with a great variety of beautiful colours, as RED, YELLOW, ORANGE, GREEN, and BLUE, variously intermixed.

233. Prepare a strong solution of phosphorus in sulphuric ether, and dip a piece of white silk in the solution; then, when the ether has evaporated, and the phosphorus begins to fume, apply a solution of nitro-muriate of gold, made by dissolving the crystals of that salt in distilled water; the silk will in an instant be covered with a SPLENDID coat of METALLIC GOLD.

234. Proceed as in the last experiment, and instead of the solution of gold, apply, with a camel's-hair pencil, a solution of nitrate of silver. Here the silver will instantly be restored to its METALLIC BRILLIANCY, and frequently attended by SPANGLES of a beautiful BLUE.

235. If a bit of white silk be immersed in an ethereal solution of gold, and dried, the application of phosphorized ether will only impart a BROWN colour to the silk; but if it be placed on the palm of the hand, as soon as the phosphorus begins to fume, and breathed on for a considerable time, the BROWN will be succeeded by a PURPLE TINGE and the METALLIC LUSTRE of the GOLD will soon begin to appear.

236. "An aqueous solution of nitro-muriate of gold," says Mrs. Fulham, "was poured into a china cup containing some phosphorized ether; instantly the gold began to assume its metallic splendour, attended with a variety of colours, as PURPLE, BLUE, and RED, the beauty of which cannot be described; but which depend on the DIFFERENT DEGREES of the reduction."

237. With a needle pass a thread through a small bit of phosphorus, previously freed from moisture by immersing it in alcohol. If this be suspended in an aqueous solution of nitro-muriate of gold, in a few minutes the PHOSPHORUS will become covered with PURE GOLD.

238. If a piece of white SILK be dipped in an aqueous solution of nitro-muriate of gold, and exposed while wet to sulphurous acid gas, the whole piece will in a few seconds be covered with a coat of REDUCED GOLD, which remains PERMANENT.

239. If a piece of white silk be immersed in an aqueous solution of nitrate of silver, thoroughly dried in the dark, and then exposed to sulphurous acid vapours, it will suffer no change; nor, if it be wetted with *alcohol* and then replaced in the vapour, will any sign of reduction appear: but if it be wetted with pure *water*, and then exposed to the vapour, METALLIC SILVER will immediately be seen on its surface. *A glass funnel is a convenient apparatus for these experiments. The silk may be suspended by a thread passed through it, and made fast to the funnel with a cork. The funnel is then to be placed on a table, and by moving it a little over the edge of the table, a lighted match may be readily introduced, and when the glass is full of vapour the match may be withdrawn The vapour is confined by sliding the funnel back upon the table; and thus the phænomena of the experiment may be easily observed.*

240. Dip a piece of white calico in an aqueous solution of acetate of lead, and then drop a little solution of sulphuret of potass upon it. If this be now placed in the palm of the hand, the LEAD will be observed gradually to revive, and will soon be reduced to its METALLIC STATE.

241. Dissolve some sulphuret of potass in alcohol, and immerse a slip of white silk in the solution. If a drop of an aqueous solution of sulphate of manganese be now applied, films of METALLIC MANGANESE, bright as silver, will instantly appear.

242. If a bit of silk be immersed in diluted acetate of lead, and exposed while *wet* to a stream of sulphuretted hydrogen gas, a brown tinge will instantly diffuse itself, like a passing shadow, over the whole surface of the silk, accompanied with a bright coat of REDUCED LEAD resembling silver.

243. If a piece of silk be immersed in an aqueous solution of muriate of tin, and exposed while *wet* to a stream of the same gas, REDUCED TIN of great brightness will immediately cover the surface, and in a little time this will be accompanied by various colours, such as BLUE, ORANGE, and PURPLE.

244. A piece of silk, treated in the same way, but dipped in an aqueous solution of muriate of arsenic, will be covered with resplendent METALLIC ARSENIC, attended with a CITRON YELLOW COLOUR.

245. Prepare two glasses of very dilute nitrate of copper; into one drop a little liquid ammonia, and into the other some diluted arseniate of potass. The addition of these two *colourless* solutions will produce very different effects; for the one glass will have an abundant precipitate of a beautiful GRASS GREEN, and the other a precipitate of a brilliant SAPPHIRE BLUE.

To read or practise the foregoing experiments merely for the sake of amusement, may occasionally have its advantages; but a resolution to repeat them, and examine all the phænomena, for the sole purpose of receiving instruction, is what the author would principally inculcate. Let it never be forgotten, that *no effect*, however extraordinary, or even trivial, it may appear to us, can ever happen but in consequence of some previously established law of unerring nature. The following apostrophe of Dr. Darwin to the Fountain of all Goodness, may possibly tend to impress this important truth upon the student's mind:—

> "Thus, at thy potent nod, *effect* and *cause*
> Walk hand in hand, accordant to thy laws;
> Rise at Volition's call, in groups combin'd,
> Amuse, delight, instruct and serve mankind."*

A VOCABULARY

OF

CHEMICAL TERMS.

ACETATES. Salts formed by the combination of any base with the acetic acid. See page 279.

ACIDS. For the nature of acids see page 206.

—— *oxygenized.* Acids combined with an additional quantity of oxygen, for particular purposes. The oxygenized muriatic acid used in bleaching is an instance of this super-oxygenizement. See page 222.

—— *hyperoxygenized.* Acids which are oxygenized to a maximum. See page 267.

ACIDULES. A term applied to the natural combination of some acids with a portion of potash. The oxalic acid and the tartaric are the only acids that have hitherto been found in this state of semi-saturation. See page 261.

AËRIFORM *fluids.* Fluid substances combined with an additional portion of caloric sufficient to give them the gaseous form. See *gas.*

AFFINITY, *chemical.* A term used to express that peculiar propensity which different species of matter have to unite with each other, or with portions of matter of their own species. See chap. 13.

—— *of aggregation.* A force by which two bodies of the *same* kind tend to unite, and by which an aggregate is formed without the *chemical* properties of the substances being at all changed. See page 472.

—— *of composition.* A force by which substances of *different* kinds unite, and by which matter is formed whose properties are different from those of the bodies before their combination. This attraction is stronger in proportion as the nature of the bodies is different, between which it is exerted. See page 475.

AGGREGATES. Substances whose parts are united by cohesive, and not by chemical attraction. See *Affinity of aggregation.* See page 470.

ALBUMEN. The modern name for coagulable lymph. It is that peculiar animal substance which forms the serum of the blood, the white of eggs, and other compounds.

ALCOHOL. Rectified spirit of wine. When good, its specific gravity is only 0.836. See page 348.

ALEMBIC. The term formerly given to the still used by chemists for their distillations.

ALKALIES. Peculiar substances which have an urinous, burning, and caustic taste, and a strong tendency to combination. When united with acids they form mild alkaline salts. See page 179.

ALLOYS. A combination of any two metals, except mercury, is called an alloy. Thus gold is alloyed either with silver or copper, for the purposes of coinage.

ALLUVIAL. By alluvial depositions is meant the soil which has been formed by the destruction of the mountains, and the washing down of their particles by torrents of water. See page 300.

AMALGAM. A combination or mixture of mercury with any other metal, is called an amalgam.

AMMONIACAL *salts.* Salts formed with ammonia, or volatile alkali. See page 201.

ANALYSIS. The resolution of a substance into its constituent parts, for the purpose of examination. See page 28.

ANNEALING. The art of rendering substances tough which are naturally hard and brittle. Glass and iron are annealed by gradual cooling; brass and copper by heating, and then suddenly plunging them in cold water.

APPARATUS, *chemical.* This term is descriptive of all the utensils made use of in a chemical laboratory. The principal are stills, furnaces, crucibles, retorts, receivers, matrasses, worm tubs, pneumatic troughs, thermometers, &c.

AREÖMETER. A graduated glass instrument with a bulb, by which the specific gravity of liquids is ascertained. Baumé's areömeter is that which is chiefly referred to when the French writers speak of this instrument. See table page 537.

ARGILLACEOUS. A term descriptive of those earths which contain alumine or clay.

AROMA. A term used for the odour which arises from certain vegetables, or their infusions.

ARSENIATES. Salts formed by the combination of any base with the acid of arsenic. See page 277.

ATMOSPHERES. We use this term to express the degree of additional pressure given to fluids. Thus, if, in order to impregnate water with any of the gases, I give it a pressure of 15lbs. upon every square inch of surface, I am said to give it *one* atmosphere; if 30lbs. *two* atmospheres, &c. &c. See page 63.

ATTRACTION. Chemical attraction is a term synonymous with *affinity*; which see.

AZOTE. A name given by the French chemists to *nitrogen*, to which, being the most proper, the reader is referred.

B

BALLOON. A term given by the French to their spherical chemical receivers.

BALSAMS. Certain aromatic resinous substances, which are obtained from some trees by incisions. Of this kind are the Canada balsam, the balsam of Copaiva, the balsam of Tolu, &c.

BAROMETER. An instrument which shows the variation of the pressure of the atmosphere, by the rise or fall of a column of mercury in a graduated glass tube. See note *, page 46.

BASE. A chemical term, usually applied to denote the earth, the alkali, or the metal which is combined with an acid to form a salt.

BATHS. Vessels for distillation or digestion, contrived to transmit heat gradually and regularly.

——— *sand.* Vessels filled in part with dry sand, in which those retorts are placed which require a greater heat than can be given by boiling water. In large works iron plates are used instead of vessels of capacity. They are often called *sand-heats*.

——— *water.* Vessels of boiling water, in which other vessels containing the matters to be distilled or digested are placed, in order that the same heat may be kept up throughout the whole of any particular process.

BENZOATES. Salts formed by the combination of any base with the benzoic acid.

BITTERN. The mother-liquor which remains after the crystallization of muriate of soda (sea salt). It generally contains sulphate of magnesia, and a small portion of sulphate of soda.

BITUMEN. A generic term, applied to a variety of fossil inflammable substances. See notes, page 328.

BLOW-PIPE. An instrument to increase and direct the flame of a lamp for the analysis of minerals, and for other chemical purposes.

BOLT-HEAD. A round chemical vessel with a long neck, usually employed for digestions. It is also called a matrass.

BORATES. Salts formed by the combination of any base with the acid of borax. See page 276.

BUTTON. A name given to the small round piece of metal which is found at the bottom of a crucible after a metallic ore or an oxide of metal has been reduced.

C.

CALCAREOUS. A chemical term formerly applied to describe chalk, marble, and all other combinations of lime with carbonic acid. See page 163.

CALCINATION. The application of heat to saline, metallic, or other substances; so regulated as to deprive them of moisture, &c., and yet preserve them in a pulverulent form.

CALORIC. The chemical term for the matter of heat.

———— *free.* Is caloric in a separate state, or, if attached to other substances, not *chemically* united with them. See page 93.

———— *latent.* Is the term made use of to express that portion of caloric which is chemically united to any substance, so as to become a *part* of the said substance. See page 94.

CALORIMETER. An instrument for ascertaining the quantity of caloric disengaged from any substance that may be the object of experiment. See page 100.

CALX. An old term made use of to describe a metallic oxide.

CAMPHORATES. Salts formed by the combination of any base with the camphoric acid. See page 280.

CAPILLARY. A term usually applied to the rise of the sap in vetetables, or the rise of any fluid in very small tubes; owing to a peculiar kind of attraction, called capillary attraction.

CAPSULES. Are small saucers of clay for roasting samples of ores, and for smelting them to ascertain their value.

CAPUT-MORTUUM. A term signifying *dead-head,* being that which remains in a retort after distillation to dryness. See *residuum,* which is the modern term.

CARBON. The basis of charcoal. See page 320.

CARBONATES. Salts formed by the combination of any base with carbonic acid. See page 271.

CARBURETS. Compound substances, of which carbon forms one of the constituent parts. Thus plumbago, which is composed of carbon and iron, is called carburet of iron. See page 337.

CAUSTICITY. That quality in certain substances by which they burn or corrode animal bodies to which they are applied. It is best explained by the doctrine of chemical affinity. See note †, page 180.

CEMENTATION. A process by which metals are purified or changed in their qualities by heat, without fusion, by means of a composition, called a cement, with which they are covered. Thus iron, by being kept a long time in a certain degree of heat, surrounded by charcoal powder, is converted into steel.

CHALYBEATE. A term descriptive of those mineral waters which are impregnated with iron. See *Martial.*

CHARCOAL. Wood burnt in close vessels: it is an oxide of carbon, and generally contains a small portion of salts and earth. Its carbonaceous matter may be converted by combustion into carbonic acid gas. See page 321.

CHATOYANT. A term much used lately by the French chemists to describe a property in some metallic and other substances, of varying their colours according to the way in which they are held; as is the case with the feathers of some birds, which appear very different when seen in different positions.

CHERT. A term made use of in describing a species of siliceous stones, which are coarser and softer than the common silex. It is often found in large masses in quarries of limestone.

CHROMATES. Salts formed by the combination of any base with the chromic acid. See page 235.

CITRATES. Salts formed by the combination of any base with citric acid. See page 281.

COAL. A term applied to the residuum of any dry distillation of animal or vegetable matters. See page 327.

COHESION. A force inherent in all the particles of all substances, excepting light and caloric, which prevents bodies from falling in pieces. See *Affinity.*

COHOBATION. When a distilled fluid is poured again upon the matter from which it was distilled, in order to make it stronger, it is called cohobation. It is not much practised by modern chemists.

COLUMBATES. Salts formed by the combination of any base with the columbic acid. See page 249.

COMBINATION. A term expressive of a true *chemical* union of two or more substances; in opposition to mere mechanical mixture.

COMBUSTIBLES. Certain substances which are capable of combining more or less rapidly with oxygen. They are divided by chemists into simple and compound combustibles. See page 452.

COMBUSTION. The act of absorption of oxygen by combustible bodies from atmospheric or vital air. The word decombustion is sometimes used by the French writers to signify the opposite operation. See page 451.

COMMINUTION. The reduction of hard bodies into small particles. By this process the heaviest substances may be made to float in the lightest fluids.

CONCENTRATION. The act of increasing the specific gravity of bodies. The term is usually applied to fluids which are rendered stronger by evaporating a portion of the water which they contain.

CONDENSATION. The act of bringing the component parts of vapour, or gas, nearer together by pressure, or by cold. Thus atmospheric air may be condensed by pressure, and aqueous vapour by the subtraction of caloric, till it is converted into water.

CRUCIBLES. Vessels of indispensable use in chemistry in the various operations of fusion by heat. They are made of baked earth, or metal, in the form of an inverted cone.

CRYSTALLIZATION. An operation of nature, in which various earths, salts, and metallic substances, pass from a fluid to a solid state, assuming certain determinate geometrical figures. See page 284.

—————— —————— *water of*. That portion which is combined with salts in the act of crystallizing, and becomes a *component* part of the said saline substances. See page 288.

CUPEL. A vessel made of calcined bones, mixed with a small proportion of clay and water. It is used whenever gold and silver are refined by melting them with lead. The process is called cupellation.

D.

DECOMBUSTION. Synonymous with deoxidizement; which see.

DECOMPOSITION. The separation of the constituent principles of compound bodies by chemical means.

DECREPITATION. The sudden decomposition of salts, attended with a crackling noise when thrown into a red-hot crucible, or on an open fire.

DEFLAGRATION. The vivid combustion that is produced whenever nitre, mixed with an inflammable substance, is exposed to a red heat. It may be attributed to the extrication of oxygen from the nitre, and its being transferred to the inflammable body; as any of the nitrates or oxygenized muriates will produce the same effect.

DELITE. A term used by some of the French writers, signifying to break, by the action of the air, like a soft stone into layers. See Annales de Chimie, tom. xix. 79.

DELIQUESCENCE *of solid saline bodies,* signifies their becoming moist, or liquid, by means of water which they absorb from the atmosphere in consequence of their great attraction for that fluid. See page 289.

DELIQUIUM. Is the state of potash, or any deliquescent salt, when it has so far deliquesced by exposure to the air as to have become a liquid.

DEOXIDIZE, (formerly deoxidate). To deprive a body of oxygen.

DEOXIDIZEMENT. A term made use of by some writers to express that operation by which one substance deprives another substance of its oxygen. It is called unburning a body by the French chemists.

DEPHLEGMATION. Is the act of separating the water from chemical liquors.

DEPURATION. The purging or separating any liquid in a state of purity from its fæces or lees.

DETONATION. An explosion with noise. It is most commonly applied to the explosion of nitre when thrown upon heated charcoal. See note †, page 268.

DIGESTION. The effect produced by the continued soaking of a solid substance in a liquid, with the application of heat.

DIGESTOR *Papin's.* An apparatus for reducing animal or vegetable substances to a pulp or gelly expeditiously.

DISTILLATION. A process for separating the volatile parts of a substance from the more fixed, and preserving them both in a state of separation.

DOCIMASTIC ART. The art of assaying metals.

DUCTILITY. A quality of certain bodies, in consequence of which they may be drawn out to a certain length without fracture. See page 351.

DULCIFICATION. The combination of mineral acids with alcohol. Thus we have dulcified spirit of nitre, dulcified spirit of vitriol, &c.

E

EDULCORATION. Expressive of the purification of a substance by washing with water.

EFFERVESCENCE. An intestine motion which takes place in certain bodies, occasioned by the sudden escape of a gaseous substance.

EFFLORESCENCE. A term commonly applied to those saline crystals which become pulverulent on exposure to the air, in consequence of the loss of a part of the water of crystallization. See page 289.

ELASTICITY. A force in bodies, by which they endeavour to restore themselves to the posture from whence they were displaced by any external force. See page 52.

ELASTIC FLUIDS. A name sometimes given to vapours and gases. Vapour is called an *elastic* fluid; gas, a *permanently* elastic fluid.

ELECTIVE ATTRACTIONS. A term used by Bergman and others to designate what we now express by the words chemical *affinity*; which see. When chemists first observed the power which one compound substance has to decompose another, it was imagined that the minute particles of some bodies had a *preference* for some other particular bodies; hence this property of matter acquired the term *elective* attraction. See chapter 13.

ELEMENTS. The simple, constituent parts of bodies, which are incapable of decomposition; they are frequently called principles. See "Simple Substances."

ELIQUATION. An operation whereby one substance is separated from another by fusion. It consists in giving the mass a degree of heat that will make the more fusible matter flow, and not the other.

ELUTRIATION. The operation of pulverizing metallic ores or other substances, and then mixing them with water, so that the lighter parts which are capable of suspension may be poured off, and thus separated from the grosser particles. The metallic substances which are reduced to an impalpable powder are prepared by this process.

EMPYREUMA. A peculiar and indescribably disagreeable smell, arising from the burning of animal and vegetable matter in close vessels.

EOLIPILE. A copper vessel with a small orifice, and partly filled with water. It is made hot, in order that the vapour of the water may rush out with violence, and carry a stream of air with it to increase the intensity of fires. It is an instrument of great antiquity.

ESSENCES. What are called essences, in chemistry and pharmacy, are the essential oils obtained by distillation from odoriferous vegetable substances.

ESSENTIAL SALTS. The saline substances found in plants, and which are held in solution by the water wherein they are infused. They are obtained by evaporation and cooling.

ETHERS. Volatile liquids formed by the distillation of some of the acids with alcohol.

EVAPORATION. The conversion of fluids into vapour by heat. This appears to be nothing more than a gradual solution of the aqueous particles in atmospheric air, owing to the chemical attraction of the latter for water.

EUDIOMETER. An instrument invented by Dr. Priestley for determining the purity of any given portion of atmospheric air. The science of investigating the different kinds of gases is called *eudiometry*.

EXPRESSION. A term used in pharmacy, denoting the act of forcing out the juices and oils of plants by means of a press. By a similar term the *expressed* are distinguished from the *essential* oils.

EXSICCATION. The act of drying moist bodies. It is effected in two ways; by exhaling the aqueous particles by the application of heat or atmospheric air, and by absorbing the moisture with soft and spongy substances. Thus, small matters are dried by chemists with bibulous paper; and larger masses, by spreading them on tablets of chalk.

EXTRACTS. The soluble parts of vegetable substances, first dissolved in spirit or water, and then reduced to the consistence of a thick syrup, or paste, by evaporation.

F.

FAT. An oily concrete animal substance, composed of oil, sebacic acid, and carbon.

FERMENTATION. A peculiar spontaneous motion, which takes place in all vegetable matter when exposed for a certain time to a proper degree of temperature. For the changes which are effected by saccharine fermentation, see page 346.

FIBRINE. That white fibrous substance which is left after freely washing the coagulum of the blood, and which chiefly composes the muscular fibre.

FILTRATION A chemical process for the depuration of liquid substances. Bibulous paper supported by a funnel is commonly made use of; but for dear and expensive liquors chemists generally use a little carded cotton lightly pressed into the tube of a glass funnel, The valuable concentrated acids should be filtered through pounded glass.

FIXITY. A term applicable to that property of some bodies of bearing a great heat without being volatilized.

FLOWERS. In chemical language are solid dry substances reduced to a powder by sublimation. Thus we have flowers of arsenic, of sal ammoniac, of sulphur, &c. which are arsenic, sal ammoniac, and sulphur unaltered except in appearance.

FLUATES. Salts formed by the combination of any base with fluoric acid. See page 275.

FLUIDITY. A term applied to all liquid substances. Solids are converted to fluids by combining with a certain portion of caloric. See page 31.

FLUX. A substance which is mixed with metallic ores, or other bodies, to promote their fusion; as an alkali is mixed with silex, in order to form glass.

FOSSIL. See *Mineral*, with which it is synonymous.

FULIGINOUS. A term sometimes made use of in describing certain vapours which arise in chemical operations, having the thick appearance of smoke.

FULMINATION. Thundering, or explosion with noise. We have fulminating silver, fulminating gold, and other fulminating powders, which explode with a loud report by friction, or when slightly heated. See page 374.

FURNACES. Chemical vessels of various forms for the fusion of ores, or other operations which require heat.

———— *blast*. Are built for making iron, smelting ores, &c. They are so contrived that their heat is much increased by means of powerful bellows. A blacksmith's forge is a kind of blast furnace.

———— *wind*. Chemical furnaces for intense heat, so constructed that they draw with great force, without the use of bellows.

FUSION. The state of a body which was solid in the temperature of the atmosphere, and is now rendered fluid by the artificial application of heat.

G.

GALLATES. Salts formed by the combination of any base with gallic acid. See page 242.

GALVANISM. A new science which offers a variety of phænomena, resulting from different conductors of electricity placed in different circumstances of contact; particularly the nerves of the animal body. See page 91.

GANGUE. A term made use of to denote the stony matter which fills the cavities, and accompanies the ores in the veins of metals.

GAS. All solid substances when converted into permanently elastic fluids by caloric are called gases. See page 69.

GASEOUS. Having the nature and properties of gas.

GASOMETER. A name given to a variety of utensils and apparatus contrived to measure, collect, preserve, or mix the different gases. An apparatus of this kind is also used for the purposes of administering pneumatic medicines.

GASOMETRY. The science of measuring the gases. It likewise teaches the nature and properties of these elastic fluids.

GELATINE. A chemical term for animal gelly. It exists particularly in the tendons and the skin of animals.

GLASS. Some metallic oxides when fused are called *glass*. They have somewhat of resemblance to common glass.

——— *phosphoric*. A vitreous, insipid, insoluble substance, procured by boiling down phosphoric acid to a syrup, and then fusing it by an increased heat.

——— *gall*. See *Sandiver*.

GLUTEN. A vegetable substance somewhat similar to animal gelatine. It is the gluten in wheat-flour which gives it the property of making good bread, and adhesive paste. Other grain contains a much less quantity of this nutritious substance.

GRADUATION. A process, by evaporation, of bringing fluids to a certain degree of consistence, in order to separate more easily the substances they hold in solution.

——————. The division of a scale or measure into decimal, or other regular, parts.

GRAIN. The *smallest* weight made use of by chemical writers. Twenty grains make a scruple; 3 scruples a drachm; 8 drachms, or 480 grains, make an ounce; 12 ounces, or 5760 grains, a pound troy. The *averdupois* pound contains 7000 grains.

GRANULATION. The operation of pouring a *melted* metal into water, in order to divide it into small particles for chemical purposes. Tin is thus granulated by the dyers before it is dissolved in the proper acid.

GRAVITY. That property by which bodies move towards each other, in proportion to their respective *quantities* of matter. This is the property by which bodies fall to the earth. See chapter 13.

——— *specific*. This differs from absolute gravity in as much as it is the weight of a given *measure* of any solid or fluid body, compared with the *same measure* of distilled water. It is generally expressed by decimals. See page 36.

GUMS. Mucilaginous exudations from certain trees. Gum consists of lime, carbon, oxygen, hydrogen, and nitrogen, with a little phosphoric acid.

H.

HEAT *matter of.* See *Caloric.*

HEPAR. The name formerly given to the combination of sulphur with alkali. It is now called sulphuret of potass, &c., as the case may be.

HEPATIC *gas.* The old name for sulphuretted hydrogen.

HERMETICALLY. A term applied to the closing of the orifice of a glass tube, so as to render it air-tight. Hermes, or Mercury, was formerly supposed to have been the inventor of chemistry; hence a tube which was closed for chemical purposes, was said to be Hermetically or chemically sealed. It is usually done by melting the end of the tube by means of a blow-pipe.

HYDROGEN. A simple substance; one of the constituent parts of water. See page 305.

———— *gas.* Solid hydrogen united with a large portion of caloric. It is the lightest of all the known gases. It is used on this account to inflate balloons. It was formerly called inflammable air.

HYDRO-CARBONATES. Combinations of carbon with hydrogen are described by this term. Hydro-carbonate gas is procured from moistened charcoal by distillation. See page 311.

HYDROGENIZED *sulphurets.* Certain bases combined with sulphuretted hydrogen.

HYDRO-OXIDES. Metallic oxides combined with water.

HYDROMETERS. Instruments for ascertaining the specific gravity of spirituous liquors or other fluids.

HYGROMETERS. Instruments for ascertaining the degree of moisture in atmospheric air.

HYPEROXYGENIZED. A term applied to substances which are combined with the largest possible quantity of oxygen. We have muriatic acid, oxygenized muriatic acid, and hyperoxygenized muriatic acid. The latter can be exhibited only in combination. See page 267.

I.

INCINERATION. The burning of vegetables for the sake of their ashes. It is usually applied to the burning of kelp on the coasts for making mineral alkali.

INFLAMMATION. A phænomenon which takes place on mixing certain substances. The mixture of oil of turpentine with strong nitrous acid is an instance of this peculiar chemical effect.

INFUSION. A simple operation to procure the salts, juices, and other virtues of vegetables by means of water.

INSOLATION. A term sometimes made use of to denote that exposure to the sun which is made in order to promote the chemical action of one substance upon another.

INTEGRANT *particles*. See note *, page 302.

INTERMEDIATES. A term made use of when speaking of chemical affinity. Oil, for example, has no affinity to water unless it be previously combined with an alkali; it then becomes soap, and the alkali is said to be the *intermedium* which occasions the union.

K.

KALI. A genus of marine plants which is burnt to procure mineral alkali by afterwards lixiviating the ashes. See page 184.

L.

LABORATORY. A room fitted up with apparatus for the performance of chemical operations.

LACTATES. Salts formed by the combination of any base with lactic acid. See page 242.

LAKES. Certain colours made by combining the colouring matter of cochineal, or of certain vegetables, with pure alumine, or with oxide of tin, zinc, &c.

LAMP ARGAND'S. A kind of lamp much used for chemical experiments. It is made on the principle of a wind furnace, and thus produces a great degree of light and heat without smoke.

LENS. A glass, convex on both sides, for concentrating the rays of the sun. It is employed by chemists in fusing refractory substances which cannot be operated upon by an ordinary degree of heat. See note, page 112.

LEVIGATION. The grinding down of hard substances to an impalpable powder on a stone with a muller, or in a mill adapted to the purpose.

LIQUEFACTION. The change of a solid to the state of a fluid, occasioned by the combination of caloric. See page 32.

LITHARGE. An oxide of lead which appears in a state of vitrification. It is formed in the process of separating silver from lead. See note §, page 399.

LIXIVIATION. The solution of an alkali or a salt in water, or in some other fluid, in order to form a lixivium.

LIXIVIUM. A fluid impregnated with an alkali or with a salt.

LUTE. A composition for closing the junctures of chemical vessels to prevent the escape of gas or vapour in distillation. See Additional Notes, No. 54.

M.

MACERATION. The steeping of a solid body in a fluid in order to soften it, without impregnating the fluid.

MALATES. Salts formed by the combination of any base with malic acid. See page 241.

MALLEABILITY. That property of metals which gives them the capacity of being extended and flattened by hammering. It is probably occasioned by latent caloric. See page 351.

MARTIAL. An old term for chemical preparations of iron. See *Chalybeate.*

MASSICOT. A name given to the *yellow* oxide of lead, as minium is applied to the *red* oxide.

MATRASS. Another name for a bolt-head; which see.

MATRIX. The bed in which a metallic ore is found. See page 351.

MATT. That mass of metal which separates from the scoriæ in smelting ores without previous roasting.

MENSTRUUM. The fluid in which a *solid* body is dissolved. Thus water is a menstruum for salts, gums, &c., and spirit of wine for resins.

METALLIC OXIDES. Metals combined with oxygen. By this process they are generally reduced to a pulverulent form; are changed from combustible to incombustible substances; and receive the property of being soluble in acids. See page 440.

METALLURGY. The art of extracting and purifying metals. See page 352.

MINERAL. Any natural substance of a metallic, earthy, or saline nature, whether simple or compound, is deemed a mineral.

MINERALIZERS. Those substances which are combined with metals in their ores; such are sulphur, arsenic, oxygen, carbonic acid, &c. See page 352.

MINERALOGY. The science of fossils and minerals.

MINERAL WATERS. Waters which hold some metal, earth, or salt, in solution. They are frequently termed Medicinal Waters.

MINIUM. The red oxide of lead. See note ‡, page 435.

MOLECULE. The molecules of bodies are those ultimate particles of matter which cannot be decomposed by any chemical means. See page 302.

MOLYBDATES. Salts formed by the combination of any base with the molybdic acid. See page 235.

MORDANTS. Substances which have a chemical affinity for particular colours; they are employed by dyers as a bond to unite the colour with the cloth intended to be dyed. See page 10.

MOTHER-WATERS, or Mothers. The liquors which are left after the crystallization of any salts. See page 286.

MUCILAGE. A glutinous matter obtained from vegetables, transparent and tasteless, soluble in water, but not in spirit of wine. It chiefly consists of carbon and hydrogen, with a little oxygen.

MUCITES. Salts formed by the combination of any base with the mucous acid. See page 243.

MUFFLE. A semi-cylindrical utensil, resembling the tilt of a boat, made of baked clay; its use is that of a cover to cupels in the assay furnace, to prevent the charcoal from falling upon the metal, or whatever is the subject of experiment.

MURIATES. Salts formed by the combination of any base with muriatic acid. See page 265.

N.

NATRON. One of the names for mineral alkali, or soda.

NEUTRALIZE. When two or more substances mutually disguise each other's properties, they are said to neutralize one another.

NEUTRAL SALT. A substance formed by the union of an acid with an alkali, an earth, or a metallic oxide, in such proportions as to saturate both the base and the acid.

NITRATES. Salts formed by the combination of any base with nitric acid. See page 269.

NITROGEN. A simple substance, by the French chemists called azote. It enters into a variety of compounds, and forms more than three parts in four of atmospheric air. See page 74.

O.

OCHRES. Various combinations of the earths with oxide, or carbonate, of iron.

OIL. A fluid substance well known. It is composed of hydrogen, oxygen, and carbon.

ORES. Metallic earths, which frequently contain several extraneous matters; such as sulphur, arsenic, &c.

OXALATES. Salts formed by the combination of any base with oxalic acid. See page 279.

OXIDE. Any substance combined with oxygen, in a proportion not sufficient to produce acidity.

OXIDIZE. To combine oxygen without producing acidity.

OXIDIZEMENT. The operation by which any substance is combined with oxygen, in a degree not sufficient to produce acidity.

OXYGEN. A simple substance composing the *greatest* part of water, and part of atmospheric air. (See pages 73 and 431.)

——— *gas.* Oxygen converted to a gaseous state by caloric. It is also called vital air. It forms nearly one-fourth of atmospheric air.

OXYGENIZE. To acidify a substance by oxygen. Synonymous with Oxygenate.

OXYGENIZABLE. A term applicable to all bodies that combine with oxygen, and do not emit flame during the combination.

OXYGENIZEMENT. The production of acidity by oxygen. See page 207.

P.

PARTING. The operation of separating gold from silver by means of nitrous acid, and other mediums. See page 20.

PELICAN. A glass alembic, with a tubulated capital, from which two opposite and crooked arms pass out, and enter again at the swell of the vessel. The instrument is designed for operations of cohobation, and is calculated to save the trouble of frequently luting and unluting the apparatus. It is now seldom used.

PELLICLE. A thin skin which forms on the surface of saline solutions and other liquors, when boiled down to a certain strength.

PHLOGISTON. An old chemical name for an imaginary substance, supposed to be a combination of fire with some other matter, and a constituent part of all inflammable bodies, and of many other substances.

PHOSPHATES. Salts formed by the combination of any base with phosphoric acid. See page 272.

PHOSPHITES. Salts formed by the combination of any base with phosphorous acid. See page 274.

PHOSPHURETS. Substances formed by an union with phosphorus. Thus we have phosphuret of lime, phosphuretted hydrogen, &c. See page 320.

PLUMBAGO. Carburet of iron, or the *black-lead* of commerce. See page 337.

PNEUMATIC. Any thing relating to the airs and gases.

——— *trough*. A vessel filled in part with water or mercury, for the purpose of collecting gases, so that they may be readily removed from one vessel to another. See note, page 70.

PRECIPITATE. Any matter which, having been dissolved in a fluid, falls to the bottom of the vessel on the addition of some other substance capable of producing a decomposition of the compound, in consequence of its attraction either for the menstruum, or for the matter which was before held in solution.

PRECIPITATION. That chemical process by which bodies dissolved, mixed, or suspended in a fluid, are separated from that fluid, and made to gravitate to the bottom of the vessel.

PRINCIPLES OF BODIES. Synonymous with *Elements*; which see.

PRUSSIATES. Salts formed by the combination of any base with prussic acid. See page 283.

PUTREFACTION. The last fermentative process of nature, by which organized bodies are decomposed so as to separate their principles, for the purpose of reuniting them by future attractions, in the production of new compositions.

PYRITES. An abundant mineral found on the English coasts, and elsewhere. Some are sulphurets of iron, and others sulphurets of copper, with a portion of alumine and silex. The former are worked for the sake of the sulphur, and the latter for sulphur and copper. They are also called Marcasites and Firestone.

——— *martial*. That species of pyrites which contains iron for its basis. See a full account of these minerals in Henckel's Pyritologia.

PYROMETER. An instrument invented by Mr. Wedgwood for ascertaining the degrees of heat in furnaces and intense fires. See Philosophical Transactions, vols. lxii. and lxiv. and Chemical Catch. page 102.

PYROPHORI. Compound substances which heat of themselves, and take fire on the admission of atmospheric air. See an account of a variety of experiments with these compositions in Wiegleb's Chemistry, page 622, &c.

Q.

QUARTATION. A term used by refiners in a certain operation of parting. See Lewis's Com. Tech. and page 20.

QUARTZ. A name given to a variety of siliceous earths, mixed with a small portion of lime or alumine. Mr. Kirwan confines the term to the *purer* kind of silex. Rock crystal and the amethyst are species of quartz.

R.

RADICALS. A chemical term for the *Elements* of bodies; which see.

———— *compound.* When the base of an acid is composed of two or more substances, it is said that the acid is formed of a *compound* radical. The sulphuric acid is formed with a *simple* radical; but the vegetable acids which have radicals composed of hydrogen and carbon are said to be acids with compound radicals.

REAGENTS. Substances which are added to mineral waters or other liquids as tests to discover their nature and composition. See *Test.*

REALGAR. Red sulphuretted oxide of arsenic.

RECEIVERS. Globular glass vessels adapted to retorts for the purpose of preserving and condensing the volatile matter raised in distillation.

RECTIFICATION. Is nothing more than the re-distilling a liquid to render it more pure, or more concentrated, by abstracting only a part.

REDUCTION. The restoration of metallic oxides to their original state of metals; which is usually effected by means of charcoal and fluxes. See page 442.

REFINING. The process of separating the perfect metals from other metallic substances, by what is called cupellation. See page 441.

REFRACTORY. A term applied to earths or metals that are either infusible, or that require an extraordinary degree of heat to change or melt them.

REFRIGERATORY. A contrivance of any kind, which, by containing cold water, answers the purpose of condensing the vapour or gas that arises in distillation. A worm-tub is a refrigeratory.

REGISTERS. Openings in chimneys, or other parts of chemical furnaces, with sliding doors, to regulate the quantity of atmospheric air admitted to the fire-place, or to open or shut the communication with the chimney at pleasure.

REGULUS. In its chemical acceptation, signifies a pure metallic substance, freed from all extraneous matters.

REPULSION. A principle whereby the particles of bodies are prevented from coming into actual contact. It is thought to be owing to *caloric*, which has been called the repulsive power. See chap. 13.

RESIDUUM. What is left in a pot or retort after the more valuable part has been drawn off. Thus the sulphate of potass which remains in the pot after the distillation of nitrous acid is called the residuum. It is sometimes called the *caput mortuum*.

RESINS. Vegetable juices concreted by evaporation either spontaneously, or by fire. Their characteristic is solubility in alcohol, and not in water. It seems that they owe their solidity chiefly to their union with oxygen.

RETORT. A vessel in the shape of a pear, with its neck bent downwards, used in distillation; the extremity of which neck fits into that of another bottle called a receiver.

REVERBERATORY. An oven or furnace in which the flame is confined by a dome which occasions it to be beat down upon the floor of the furnace before it passes into the chimney. Some are so contrived that it returns or reverberates upon the matter under operation.

REVIVIFICATION. See *Reduction*, which is a synonymous term: though "revivification" is generally used when speaking of quicksilver.

ROASTING. A preparative operation in metallurgy to dissipate the sulphur, arsenic, &c., with which a metal may be combined.

ROCK-CRYSTAL. Crystallized silex. See page 145.

S.

SACCOLATES. Salts formed by the combination of any base with saccholactic acid. See page 243.

SALIFIABLE BASES. All the metals, alkalies, and earths, which are capable of combining with acids, and forming salts, are called salifiable bases.

SALINE. Partaking of the properties of a salt.

SALTS *neutral.* A class of substances formed by the combination to saturation of an acid with an alkali, an earth, or other salifiable base.

——— *triple.* Salts formed by the combination of an acid with two bases or radicals. The tartrate of soda and potass (Rochelle salt) is an instance of this kind of combination.

SAND *bath.* } See *Bath.*
——— *heat.* }

SANDIVER. A matter, composed of different salts, which rises as a pellicle on the surface of the pots in which glass is melted. It is used as a flux in the fusion of ores, and for other purposes. The term is probably a corruption of "Sel de verre."

SAP-COLOURS. A name given to various expressed vegetable juices of a viscid nature, which are inspissated by slow evaporation for the use of painters, &c.; sap-green, gamboge, &c. are of this class.

SAPONACEOUS. A term applied to any substance which is of the nature or appearance of soap. See page 190.

SATURATION. The act of impregnating a fluid with another substance, till no more can be received or imbibed. A fluid which holds as much of any substance as it can dissolve, is said to be saturated with that substance. A solid may in the same way be saturated with a fluid.

SEBATES. Salts formed by the combination of any base with sebacic acid. See page 248.

SELENITE. A salt existing in spring water, formed by sulphuric acid and lime. Its proper chemical name is Sulphate of Lime. See note †, page 294.

SEMI-METAL. A name formerly given to those metals which, if exposed to the fire, are neither malleable, ductile, nor fixed. It is a term not used by modern chemists.

SILICEOUS EARTHS. A term used to describe a variety of natural substances which are composed chiefly of silex; as quartz, flint, sand, &c.

SIMPLE SUBSTANCES. Synonymous with *Elements;* which see. See also page 302.

SMELTING. The operation of fusing ores for the purpose of separating the metals they contain, from the sulphur and arsenic with which they are mineralized, and also from other heterogeneous matter.

SOLUBILITY. A characteristic of most salts. See *Solution.* See also page 290.

SOLUTION. The perfect union of a solid substance with a fluid. Salts dissolved in water are proper examples of solution.

SPARS. A name formerly given to various crystallized stones; such as the fluor spar, the adamantine spar, &c. These natural substances are now distinguished by names which denote the nature of each.

SPECIFIC GRAVITY. See the word *Gravity.*

SPELTER. The commercial name of *zinc.*

SPIRIT. A term used by the early chemists to denote all volatile fluids collected by distillation.

SPIRIT PROOF. A term made use of to describe such ardent spirits as are of the same strength as the brandy of commerce, or of the specific gravity of 0.930, water being 1.000.

STALACTITES. Certain concretions of calcareous earth found suspended like icicles in caverns. They are formed by the oozing of water, through the crevices, charged with this kind of earth. See note ‡, page 144.

STEATITES. A kind of stone composed of silex, iron, and magnesia. Also called French chalk, Spanish chalk, and soap-rock.

STRATIFICATION. A chemical operation by which bodies are placed in a condition to act mutually upon each other by being arranged layer by layer, stratum super stratum, as is practised by metallurgists.

SUB-SALTS. Salts with less acid than is sufficient to neutralize their radicals. See page 261.

SUBERATES. Salts formed by the combination of any base with the suberic acid. See page 282.

SUBLIMATE. A name given to several mercurial preparations.

SUBLIMATION. A process whereby certain volatile substances are raised by heat, and again condensed by cold into a solid form. Flowers of sulphur are made in this way. The soot of our common fires is a familiar instance of this process. See *Flowers.*

SUCCINATES. Salts formed by the combination of any base with the succinic acid. See page 245.

SUGAR. A well known substance, found in a variety of vegetables, composed of oxygen, hydrogen, and carbon. See page 332.

SULPHATES. Salts formed by the combination of any base with the sulphuric acid. See page 262.

SULPHITES. Salts formed by the combination of any base with the sulphurous acid. See page 264.

SULPHURES, or SULPHURETS. Combinations of alkalies, or metals, with sulphur. See page 307.

SULPHURETTED. A substance is said to be sulphuretted when it is combined with sulphur. Thus we say Sulphuretted hydrogen, &c.

SUPER-SALTS. Salts with an excess of acid, as the supertartrate of potass. See page 261.

SYNTHESIS. When a body is examined by *dividing* it into its component parts, it is called analysis; but when we attempt to prove the nature of a substance by the *union* of its principles, the operation is called synthesis.

SYPHON. A bent tube used by chemists for drawing liquids from one vessel into another. It is sometimes called a *Crane*.

T.

TARTRATES. Salts formed by the combination of any base with the acid of tartar. See page 280.

TEMPERATURE. The absolute quantity of free caloric which is attached to any body occasions the degree of temperature of that body. See page 102.

TENACITY. Is a term used when speaking of glutinous bodies. It is also expressive of the adhesion of one substance to another.

TEST. That part of a cupel which is impregnated with litharge in the operation of refining lead. It is also the name of whatever is employed in chemical experiments to detect the several ingredients of any composition. See *Re-agent*.

TEST-PAPERS. Papers impregnated with certain chemical re-agents; such as litmus, turmeric, radish, &c. They are used to dip into fluids to ascertain by a change of colours the presence of acids and alkalies.

THERMOMETER. An instrument to show the relative heat of bodies. Fahrenheit's thermometer is that chiefly used in England. (See page 102.) Other thermometers are used in different parts of Europe. For the difference in the scale of these thermometers, see the Table at page 542.

TINCAL. The commercial name of crude borax.

TINCTURES. Solutions of substances in spirituous menstrua.

TORREFACTION. An operation similar to Roasting; which see.

TRITORIUM. A vessel used for the separation of two fluids which are of different densities. The same operation may be performed by a common funnel.

TRITURATION. A chemical operation whereby substances are united by friction. Amalgams are made by this method.

TUBULATED. Retorts which have a hole at the top for inserting the materials to be operated upon, without taking them out of the sand heat, are called *tubulated* retorts.

TUNGSTATES. Salts formed by the combination of any base with tungstic acid. See page 278.

TUTENAG. An Indian name for zinc. Chinese copper is also called by this name, which is a compound of copper, tin, and arsenic, much resembling silver in colour.

V.

VACUUM. A space unoccupied by matter. The term is generally applied to the exhaustion of atmospheric air by chemical or philosophical means.

VAPOUR. This term is used by chemists to denote such exhalations only as can be condensed and rendered liquid again at the ordinary atmospheric temperature, in opposition to those which are *permanently* elastic.

VATS. Large chemical vessels, generally of wood, for making infusions, &c.

VITAL AIR. Oxygen gas. The empyreal or fire-air of Scheele, and the dephlogisticated air of Priestley.

VITRIFICATION. When solid substances have undergone very intense heat, so as to be fused thereby, they frequently have an appearance resembling glass. They are then said to be vitrified, or to have undergone vitrification.

VITRIOLS. A class of substances, either earthy or metallic, which are combined with the vitriolic acid. Thus there is vitriol of lime, vitriol of iron, vitriol of copper, &c. These salts are now called Sulphates, because the acid which forms them is called sulphuric acid.

VITRIOLATED TARTAR. The old name for sulphate of potass.

VOLATILE ALKALI. Another name for ammonia.

VOLATILE SALTS. The commercial name for carbonate of ammonia. See page 200.

VOLATILITY. A property of some bodies which disposes them to assume the gaseous state. This property seems to be owing to their affinity for caloric.

VOLUME. A term made use of by modern chemists to express the space occupied by gaseous or other bodies.

U.

UNION *chemical.* When a mere mixture of two or more substances is made, they are said to be mechanically united; but when each or either substance forms a component part of the product, the substances have formed a *chemical* union.

USTULATION. The roasting of ores, to separate the arsenic and sulphur which mineralizes the metal. When the matter is preserved which flies off, the process is called sublimation; but when this matter is neglected, the operation is called ustulation.

W.

WATER. The most common of all fluids, composed of 85 parts of oxygen and 15 of hydrogen. See page 120.

——— *mineral.* Waters which are impregnated with mineral and other substances are known by this appellation. These minerals are generally held in solution by carbonic, sulphuric, or muriatic acid.

WAY *dry.* A term used by chemical writers when treating of analysis or decomposition. By decomposing in the dry-way, is meant, by the agency of fire.

WAY *humid.* A term used in the same manner as the foregoing, but expressive of decomposition in a fluid state, or by means of water, and chemical re-agents, or tests.

WELDING HEAT. That degree of heat in which two pieces of iron or of platina may be united by hammering.

WOLFRAM. An ore of tungsten containing also manganese and iron.

WORM-TUB. A chemical vessel with a pewter worm fixed in the inside, and the intermediate space filled with water. Its use is to cool liquors during distillation. See *Refrigeratory.*

WOULFE's *apparatus.* A contrivance for distilling the mineral acids and other gaseous substances with little loss; being a train of receivers with safety pipes, and connected together by tubes. For a full description of this most useful apparatus, see Philosophical Transactions for 1767.

Z.

ZAFFRE. An oxide of cobalt, mixed with a portion of siliceous matter. It is imported in this state from Saxony.

ZERO. The point from which the scale of a thermometer is graduated. Thus Celsius's and Reaumur's thermometers have their zero at the *freezing* point, while the thermometer of Fahrenheit has its zero at that point at which it stands when immersed in a mixture of snow and common salt. See Notes, page 103.

INDEX.

AN INDEX
TO
THE NEW MATTER
THAT HAS BEEN ADDED TO THE SECOND EDITION.

[Where a numeral only is given, it refers to the *page of the text*; all the other articles will be found in *the Notes*. A. N. signifies *Additional Notes.*]

* * *

ERRATA.

Page 11, line 3 of the notes, for *colour* read *colours*.
11, line 3 from the bottom, for *these* read *similar*.
17, line 7, read the note as a part of the text.
32, line 8 of the notes, for *begin to boil* read *evaporate*.
58, line 16 of the notes, dele the semicolon after the word *water*.
84, line 11 of the notes, for *foul air* read *carbonic acid air*.
90, line 14 of the notes, for 92 read 93.
103, last line but one, for *tolerable*, read *tolerably correct*.
107, line 3 of the notes, for 25.127° read 25127°.
111, line 7 of the notes, dele *the* before *water*.
121, line 5 of the notes, for 320 read 32.
130, line 7 of the notes, move the (;) from *then* to *it*.
137, line 15 of the notes, for 58, read 55.
144, line 3 from the bottom, for 60 read 61.
209, line 12 of the notes, for *acids* read *acid*.
282, line 11, for *genius* read *genus*.
313, line 5, for *is solid* read *is a solid*.
317, last line but two, for *flours* read *flour*.
324, line 5 of the notes, for *being* read *both*.
334, line 5 of the notes, for *follhwing* read *following*.
376, line 11 of the notes, dele *See Additional Notes, No.* 33.
461, line 24 of the notes, for *No.* 19 read *No.* 40.
464, line 8 of the notes, for 346 read 341.
516, line 15, for *to* read *of*.
560, last line but one, for *gass* read *glass*.

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