Aug 3rd [illegible] 1803

AN

EPITOME

OF

CHEMISTRY,

IN

THREE PARTS.

PART I.

NTENDED TO FACILITATE, TO THE STUDENT, THE ACQUISITION OF CHEMICAL KNOWLEDGE BY MINUTE INSTRUCTIONS FOR THE PERFORMANCE OF EXPERIMENTS.

PART II.

DIRECTIONS FOR THE ANALYSIS OF MINERAL WATERS, OF EARTHS AND STONES, OF ORES OF METALS, AND OF MINERAL BODIES IN GENERAL.

AND

PART III.

NSTRUCTIONS FOR APPLYING CHEMICAL TESTS AND REAGENTS TO VARIOUS USEFUL PURPOSES.

BY WILLIAM HENRY.

THE THIRD EDITION, CORRECTED.

LONDON:
PRINTED FOR J. JOHNSON, NO. 72, ST PAUL'S
CHURCH-YARD.

1803.

nted by C. and W. Galabin,
am-Court, London.

PREFACE.

THE small volume, which I now offer to the public, is one of humble pretensions; yet its plan and objects appear to me sufficiently distinct, from those of every other compendium of chemistry, to authorise the addition of one more to the extensive list of elementary works. The "Chemical Pocket-Book" of Mr Parkinson, and the "Description of a portable Chest of Chemistry," translated from the German of Gottling, and published in the year 1791, might perhaps, from the similarities of title and size, be supposed to have precluded the necessity of this publication. A very cursory comparison, however, of Mr Parkinson's work with this manual will evince, that the plan and objects of the two books are totally different. To the work of Mr Gottling, the present bears, indeed, a nearer resemblance, but the coincidence is not such as to supersede the utility of this Epitome. The enumeration of tests for mineral waters, the instructions for applying these reagents, and the rules for detecting adulterations, are subjects common to both. But the progress of chemical knowledge, during the last ten years, has been so rapid, as to enable me to make numeious additions to the information of Mr Gottling, and to induce me materially to vary the arrangement under which it was offered. It may be added, that the antient nomenclature of chemistry, employed throughout Mr Gottling's work, must render it nearly unintelligible to students of the reformed system.

The arranged series of experiments was suggested to me as proper for publication, by a written catalogue, which I drew up, more than two years ago, of the experiments performed during my course of chemical lectures. This I deem it necessary to state, because something similar is to be found in an excellent manual, lately published by Bouillon la Grange.

Another object, which I propose to be fulfilled by this Epitome, is, that it may serve as a companion to the collections of chemical substances, which I have been induced, by the repeated applications of students of this science, to fit up for public sale*. The utility of these collections has, hitherto, been limited, by the want of a concise but comprehensive code of instructions for their use. With the concurrent aid of the first part of this work, and of a corresponding chest of chemical reagents, the labours of the student cannot fail to be much facilitated; for one of the principal difficulties in studying the science of chemistry, experimentally, is the acquisition of a great variety of substances, ma-

---

* See the advertisement at the end of the work.

ny of which are not easy of attainment. The directions for analyzing waters, and mineral bodies in general, I shall enable any one to apply practically, by corresponding collections of chemical tests, of so small a bulk, as to add, in the least possible degree, to the incumbrances of the traveller.

In a work, professedly compiled from others, new and original information is not to be expected, and it cannot be necessary to quote all the authorities for facts. If there be any one author, to whom I owe most, it is certainly to Mr Kirwan, whose interesting and masterly works comprehend almost every subject of chemical inquiry. The directions for analyzing minerals are translated, with considerable additions and alterations, from Vauquelin's paper, in the 30th volume of the Annales de Chimie.

The introductory part of the work formed, originally, the first of a series of lectures delivered in Manchester, and was afterwards published under the title of "A general View of the Nature and Objects of Chemistry and of its Application to Arts and Manufactures." As the readers of an elementary book may be presumed to require a similar plan of instruction with the hearers of a popular course of lectures, I have thought it unnecessary to alter the form under which the essay first appeared, though a few passages are applicable chiefly to the persons originally addressed in it. Another motive for prefixing it to this edition is, that the impression is sold, and that I have no intention of reprinting it in a separate form.

To this edition I have added the recent discoveries that have been announced since the former ones. Errors and omissions, however, I fear will still be discovered; and to the candid suggestions of others, both through the channels of public and private communication, to which I am already much indebted, I trust for their future correction.

Manchester,
November 6, 1802.

CONTENTS.

PART I.

PART II.

Directions for examining Mineral Waters and Mineral Bodies in general.

PART III.

Application of chemical Tests and Reagents to various useful Purposes.

INTRODUCTION.

THE custom of prefacing a course of lectures with the history of the science which is their subject has been so long established, that it may be necessary to state, briefly, the reasons that have induced me to depart from this unvaried usage.

The history of chemistry may either be a mere history of the science, that is, of the gradual developement of the facts and doctrines of which the science is composed, or it may comprehend, also, the biography of chemists. The detail of the progress of discovery, however, concerning particular objects of chemical research, would certainly be premature at so early a period of the course. Respecting chemists themselves little can be said, at present, that can contribute to information or amusement; for, their lives, devoted to the abstract pursuits of science, have seldom been productive of events that are suited to awaken or gratify general curiosity. Our interest, indeed, respecting philosophers is seldom excited, unless by a knowledge of the additions they have made to the facts or theories of a science; and with these a lecturer may fairly presume, however the fact may really be, that his hearers, at the commencement of a course, are wholly unacquainted. It may be added, that the history of chemistry admits of little illustration from experiment; and I shall always be reluctant to bestow time on those subjects, which, requiring not the aid of an appeal to the senses, are equally well adapted for private study.

On these grounds, therefore, I hope to be excused for infringing the general plan of lectures on chemistry, and devoting to other purposes the time that would have been allotted to the history of the science. For this will be substituted a brief view of the nature and objects of chemistry, — of its connection with the arts and with other sciences, — and an outline of the plan on which the following lectures will be conducted.

Natural philosophy, in its most extensive sense, is a term comprehending every science, that has for its objects the properties and affections of matter. But it has attained, by the sanction of common language, a more limited signification;

and chemistry, though strictly a branch of natural philosophy, is generally regarded as a distinct science. Between the two it may, perhaps, be difficult to mark out precisely the line of separation; but, an obvious character of the facts of natural philosophy is, that they are always attended with sensible motion; and the determination of the laws of motion is peculiarly the office of its cultivators. Chemical changes, on the other hand, of the most important kind, often take place without any apparent motion, either of the mass or of its minute parts, and where the eye is unable to perceive that any change has occurred. The laws of gravitation, of central forces, and all the other powers that fall under the cognizance of the natural philosopher, produce, at most, only a change of place in the bodies that are influenced by them. But, in chemical changes, we may always observe an important difference in the outward properties of things. Two highly corrosive substances, by uniting chemically together, may become mild and harmless; the combination of two colourless substances may present us with a compound of brilliant complection; and the union of two fluids, with a compact and solid mass.

Chemistry, therefore, may be defined that science, the object of which is to discover and explain the changesof composition, that occur among the integrant and constituent parts of bodies.

From this definition, it may readily be conceived how wide is the range of chemical inquiry; and, by applying it to the various events that daily occur in the order of nature, we shall be enabled to separate them with accuracy, and to allot to the sciences of natural philsophy and chemistry the proper objects of the cultivation of each. Whenever a change of place is a necessary part of any event, we shall call in the aid of the former. When this condition may be dispensed with, we shall resort to chemistry for the light of its principles. But it will be often found, that the concurrence of the two sciences is essential to the full explanation of phenomena. The water of the ocean, for example, is raised into the atmosphere by its chemical combination with the matter of heat; but the clouds, that are thus formed, maintain their elevated situation by virtue of a specific gravity less than that of the lower regions of the air, a law, the discovery and application of which are due to the natural philosopher, strictly so called.

Chemistry may be considered in two views; first, as a science, that is, as a collection of general principles, or general laws, under which are arranged individual facts; and, secondly, as an art, instructing us in the practical use and application of these laws to the purposes of common life.

The possession of its general principles enables us to comprehend the relation to each other of a great variety of events that form a part of the established order of the universe, and of which we are only spectators, devoid of all power of directing or changing them. That knowledge, it may be objected, however, can be of little utility which does not enable us to alter, in the minutest circumstance, the fixed and immutable succession of things. But the indulgence of an enlightened and liberal curiosity is, surely, no mean reward of the attainment of knowledge; and the mind is not only gratified but improved, in its moral views, by tracing the connection and dependencies of all the smaller parts that fill up the great plan of Providence.

The class of natural events, that call for the explanations of chemical science, is of very considerable magnitude; and the natural philosopher (using this term in its common acceptation) is wholly incompetent to unfold their connection. He may explain, for example, on the principles of his own science, the annual and diurnal revolutions of the earth, and part of the train of consequences depending on these rotations: but here he must stop, and the chemist must trace the effects, on the earth's surface, of the heat and light derived from the sun; the absorption of heat by the various bodies on which it falls; the consequent fluidity of some and volatilization of others; the production of clouds and their condensation in the form of rain; and the effects of this rain, as well as of the sun's heat, on the animal, vegetable, and mineral, kingdoms. In these minuter changes, we shall find, there is not less excellence of contrivance, than in the stupendous movements of the planetary system. And they even interest us more nearly; because, though not more connected with our existence or comforts, yet they occur more within our sphere of observation, and our acquaintance with their laws admits of a more direct application to human affairs.

But the science of chemistry demands respect and attention, on grounds that are more likely to ensure them, even than the indulgence of an enlightened curiosity; for, it is capable of ministering to our wants and our luxuries, and teaches us to convert, to the purposes of common life, many substances, which nature presents to us in a rude and useless form. The extraction of metals from their ores; the conversion of the rudest materials into the beautiful fabrics of glass and porcelain; the production of wine, ardent spirits, and vinegar; and the dying of linen and woollen manufactures; are only a few of the arts that are dependent on chemistry for their improvement, and even for their successful practice.

It cannot, however, be denied, that all the arts, which have been mentioned, were practised in times when the rank of chemistry, as a science, was greatly degraded, and that they are daily the employment of unlettered and ignorant men. But to what does this confession amount, and how far does it prove the independence of the above arts on the science of chemistry?

The skill of an artist is compounded of knowledge and of manual dexterity. The latter, it is obvious, no science can teach. But the acquirement of experience, in other words, a talent for accurate observation of facts, and the habit of arranging facts in the best manner, may be greatly facilitated by the possession of scientific principles. Indeed, it is hardly possible to frame rules for the practice of a chemical art, or to profit by the rules of others, without an acquaintance with the general doctrines of the science. For, in all rules it is implied, that the promised effect will only take place when circumstances are precisely the same as in the case under which the rule was formed. To insure an unerring uniformity of result, the substances employed in chemical processes must be of uniform composition and excellence; or, when it is not possible to obtain them thus unvaried, the artist should be able to judge precisely of the defect or redundancy, that he may proportion his agents according to their qualities. Were chemical knowledge more generally possessed, we should hear less of failures and disappointments in chemical operations; and the artist would commence his proceedings, not, as at present, with distrust and uncertainty, but with a well-grounded expectation of success.

No one will be presumptuous enough to contend, that any art has hitherto attained the extent of its possible perfection. In all there is yet a wide scope for improvement, and an extensive range for ingenuity and invention. But from what class of men are we to expect useful discoveries? Are we to trust, as hitherto, to the favour of chance and accident, — to the fortuitous success of men not guided in their experiments by the light of any principles? Or shall we not rather endeavour to inform the artist, and to induce him to substitute, for vague and random conjecture, the torch of induction and of rational analogy? In the present imperfect state of his knowledge, the artist is even unable fully to avail himself of those fortunate accidents, by which improvements sometimes occur in his processes; because, to the eye of common observation, he has acted agreeably to established rules, and has varied in circumstances, which he can neither perceive nor appreciate. The man of science, in these instances, sees more deeply, and, by availing himself of a minute and fortuitous difference, contributes at once to the promotion of his own interest, and to the amendment of his art.

But it is the union of theory with practice that is now contended for. "And, when theoretical knowledge and practical skill are happily combined in the same person, the intellectual power of man appears in its full perfection, and fits him equally to conduct, with a masterly hand, the details of ordinary business, and to contend successfully with the untried difficulties of new and perplexing situations. In conducting the former, mere experience may frequently be a sufficient guide, but experience and speculation must be combined, to prepare us for new combinations of circumstances."* "Expert men," says Lord Bacon, "can execute and judge of particulars one by one; but the general counsels, and the plots, and the marshalling of affairs, come best from those that are learned."

This recommendation of the acquirement of scientific knowledge to artists is happily sanctioned by the illustrious success, in our days, of the application of theory to the practice of certain arts. Few persons are ignorant of the benefits that have resulted to the manufactures of this country from the inventions of Mr Watt and Mr Wedgwood; both of whom have been not less benefactors of philosophy than eminent for practical skill. The former, by a clear insight into the doctrine of latent heat, resulting, in a great

---

* Stewart's Elements of the Philosophy of the Human Mind.

measure, from his own acuteness and patience of investigation, and seconded by an unusual share of mechanical skill, has perhaps brought the steam-engine to its acme of perfection. Mr Wedgwood, aided by the possession of extensive chemical knowledge, made rapid advances in the improvement of the art of pottery; and, besides raising himself to great opulence and distinction, has created for this country a source of most profitable and extensive industry. In an art, also, which is nearly connected with the manufactures of our own town, and the improvement of which must, therefore, "come home to our business and bosoms," we owe unspeakable obligations to two speculative chemists, — to Scheele, who first discovered the oxygenated muriatic acid; and to Berthollet, who first instructed us in its application to the art of bleaching.

Examples, however, may be urged against indulgence in theory; and instances are not wanting, in which the love of speculative refinement has withdrawn men entirely from the straight path of useful industry, and led them on gradually to the ruin of their fortunes. But from such instances it would be unfair to deduce a general condemnation of theoretical knowledge. It would be the common error of arguing against things that are useful, from their occasional abuse. — In truth, projects which have, for their foundation, a dependence on chemical principles, may be undertaken with a more rational confidence, than such as have in view the accomplishment of mechanical purposes; because, in chemistry, we are better able, than in mechanics, to predict, from an experiment on a small scale, the probable issue of more extensive attempts. No one, from the successful trial of a small machine, can affirm, with unfailing certainty, that the same success will attend one on a greatly enlarged plan: for, the amount of the resistances that are opposed to motion, increases often in a ratio greater than, from theory, could ever have been foreseen. But the same law, by which the mineral alcali is extracted from a pound of common salt, must equally operate on a thousand times the quantity; and, even when we augment our proportions in this great degree, the chemical affinities, by which so large a mass is decomposed, are exerted only between very small particles. The failures of the mechanic, therefore, arise from the nature of things; they occur, because he has not in his power the means of foreseeing and calculating the causes that produce them. But, if the chemist fail in perfecting an economical scheme on a large scale, it is either because he has not sufficiently ascertained his facts on a small one, or has rashly embarked in extensive speculations, without having previously ensured the accuracy of his estimates.

The benefits we are entitled to expect from the efforts of the artist and the man of science, united in the same character, and at the same time tempered and directed by prudential wisdom, affect not only individual but national prosperity. To the support of its distinction, as a commercial nation, this country is to look for the permanency of its riches, its power, and, perhaps, even of its liberties: and this pre-eminence is to be maintained, not only by local advantages, but on the surer ground of superiority in the productions of its arts. Impressed with a full conviction of this influence of the sciences, our neighbours and rivals, the French, offer the most public and respectful incitements to the application of theory in the improvement of the chemical arts; and, with the view of promoting this object, national institutions have been formed among them, which have been already, in several instances, attended with the most encouraging success. It may be sufficient, at present, to mention, as an example, that France has supplied, from her own native resources, her enormous, and, perhaps, unequalled, consumption of nitre.

The general uses of Chemistry have been thus fully enlarged upon, because it is a conviction of the utility of the science that can alone recommend it to attentive and persevering study. It may now be proper to point out, in detail, a few of its more striking applications.

I. The art which is, of all others, most interesting, from its subserviency to wants that are interwoven with our nature, is agriculture, or the art of obtaining, from the earth, the largest crops of useful vegetables at the smallest expense.

The vegetable kingdom agrees with the animal one, in the possession of a living principle. Every individual of this kingdom is regularly organized, and requires for its support an unceasing supply of food, which is converted, as in the animal body, into substances of various forms and qualities. Each plant has its periods of growth, health, disease, decay, and death; and is affected, in all these particulars, by the varying condition of external circumstances. A perfect state of agricultural knowledge would require, therefore, not only a minute acquaintance with the structure and economy of vegetables, but with the nature and effects of the great variety of external agents, that contribute to their nutriment or influence their state of health and vigour. The former attainment, it can hardly be expected, will ever be generally made by practical farmers; and it is in bringing the agriculturist acquainted with the precise composition of soils and manures, that chemistry promises the most solid advantages. Indeed, any knowledge that can be acquired on this subject, without the aid of chemistry, must be vague and indistinct, and can neither enable its possessor to produce an intended effect with certainty, nor be communicated to others in language sufficiently intelligible. Thus we are told, by Mr Arthur Young, that in some parts of England any loose clay is called marl, in others marl is called chalk, and in others clay is called loam. From this confused application of terms, all general benefits of experience in agriculture must be greatly limited.

Chemistry may, to agriculturists, become a universal language, in which the facts, that are observed in this art, may be so clothed as to be intelligible to all nations and ages. It would be desirable, for example, when a writer speaks of clay, loam, or marl, that he should explain his conception of these terms, by stating the chemical composition of each substance expressed by them. For, all the variety of soils and manures, and all the diversified productions of the vegetable kingdom, are capable of being resolved, by chemical analysis, into a small number of elementary ingredients. The formation of a well-defined language, expressing the proportion of these elements in the various soils and manures, now so vaguely characterised, would give an accuracy and precision, hitherto unknown, to the experience of the tillers of the earth.

It has been said, by those who contend for pure empiricism in the art of agriculture, that it has remained stationary, notwithstanding all improvements in the sciences, for more than 2000 years. "To refute this assertion," says Mr Kirwan, "we need only compare the writings of Cato, Collumella, or Pliny, with many modern tracts, or, still better, with the modern practice of our best farmers." "If the exact connection of effects with their causes," he adds, has not been so fully and extensively traced in this as in other subjects, we must attribute it to the peculiar difficulty of the investigation. In other subjects, exposed to the joint operation of many causes, the effect of each, singly and exclusively taken, may be particularly examined, and the experimenter may work in his laboratory with the object always in his view. But the secret processes of vegetation take place in the dark, exposed to the various and indeterminable influences of the atmosphere, and require, at least, half a year for their completion. Hence the difficulty of determining on what peculiar circumstance success or failure depends; for, the diversified experience of many years can alone afford a rational foundation for solid, specific, conclusions*."

II. To those who study medicine as a branch of general science, or with the more important view of practical utility, chemistry may be recommended with peculiar force and propriety.—The animal body may be regarded as a living machine, obeying the same laws of motion as are daily ex-

---

* See Kirwan on Manures.

emplified in the productions of human art. The arteries are long, flexible, and elastic, canals, admitting, in some measure, the application of the doctrine of hydraulics; and the muscles are so many levers of precisely the same effect with those which are employed to gain power in mechanical contrivances. But there is another view, in which, with equal justice, the living body may be contemplated. It is a laboratory, in which are constantly going forwards processes of various kinds, dependent on the operation of chemical affinities. The conversion of the various kinds of food into blood, a fluid of comparatively uniform composition and qualities; the production of animal heat by the action of the air on that fluid, as it passes through the lungs; and the changes, which the blood afterwards undergoes in its course through the body; are all exclusively subjects of chemical inquiry. To these, and many other questions of physiology, chemistry has of late years been applied with the most encouraging success; and it is to a long continued prosecution of the same plan that we are to look for a system of physiological science, which shall derive new vigour and lustre from the passing series of years. It would be easy to enlarge on this subject, but there are others more generally interesting, and to them, therefore, let us hasten.

III. There is an extensive class of arts, forming, when viewed collectively, a great part of the objects of human industry, which do not, on a loose and hasty observation, present any general principle of dependency or connection. But they appear thus unconnected, because we have been accustomed to attend only to the productions of these arts, which are, in truth, subservient to widely different purposes. Who would conceive, for instance, that iron and common salt, the one a metal, the use of which results from its hardness, ductility, and malleability, the other a substance, chiefly valuable from its acting as a preservative and seasoner of food, are furnished by arts alike dependent on the general principles of chemistry? The application of science, in discovering the principles of these arts, constitutes what has been termed economical chemistry; amongst the numerous objects of which, the following stand most distinguished:

1st. Metallurgy, or the act of extracting metals from their ores, comprehending that of assaying, by which we are enabled to judge, from the composition of a small portion, of the propriety of working large and extensive strata. To the metallurgist, also, belong the various modifications of the metals when obtained, and the union of them together, in different proportions, so as to afford compounds adapted to particular uses. — Throughout the whole of this art, much practical knowledge may be suggested by attention to the general doctrines of chemistry. The artist may receive useful hints respecting the construction of furnaces for the fusion of ores and metals; the employment of the proper fluxes; the utility of the admission or exclusion of air; and the conversion of the refuse of his several operations to useful purposes. When the metals have been separated from their ores, they are to be again subjected to various chemical processes. Cast or pig iron is to be changed into the forms of wrought or malleable iron and of steel. Copper, by combination with zinc or tin, affords the various compounds of brass, pinchbeck, bell-metal, gun-metal, &c. Even the art of printing owes something of its present unexampled perfection to the improvement of the metal of types.

2d. Chemistry is the foundation of those arts that furnish us with saline substances, an order of bodies highly useful in the businesses of common life. Amongst these, the most conspicuous are, sugar in all its various forms; the vegetable and mineral alcalis, known in commerce by the names of potash, pearlash, and barilla; common salt; green and blue vitriol, and alum; nitre or saltpetre; sugar of lead; borax; and a long catalogue, which it is needless to extend farther.

3d. The manufacturer of glass, and of various kinds of pottery and porcelain, should be thoroughly acquainted with the nature of the substances he employs; with their fusibility, as affected by difference of proportion, or by the admixture of foreign ingredients; with the means of regulating and measuring high degrees of heat; with the principles on which depend the hardness of his products, and their fitness for bearing the vicissitudes of heat and cold; and with the chemical properties of the best adapted colours and glazings.— Even the humble art of making bricks and tiles has received, from the chemical knowledge of Bergman, the addition of several interesting facts.

4th. The preparation of various kinds of fermented liquors, of wine, and ardent spirits, is intimately connected with chemical principles. Malting, the first step in the production of some of these liquors, consists in the conversion of part of the grain into saccharine matter, essential in every instance to the success of the fermentative change. To acquire a precise acquaintance with the circumstances, that favour or injure the process of fermentation, no small share of chemical knowledge is required. The brewer should be able to ascertain and regulate exactly the strength of his infusions, which will vary greatly when he has seemingly followed the same routine. He should be aware of the influence of minute changes of temperature in retarding or advancing fermentation; of the means of promoting it by proper ferments; and of the influence of the presence or exclusion of atmospherical air. A complete acquaintance with the chemical principles of his art can hardly fail to afford him essential aid in its practice.

The production of ardent spirits is only a sequel of the vinous fermentation, and is, therefore, alike dependent on the doctrines of chemistry.

5th. The arts of bleaching, dyeing, and printing, are throughout a tissue of chemical operations. It is not unusual to hear the new mode of bleaching distinguished by the appellation of the chemical method; but it is, in fact, not more dependent on the principles of this science than the one which it has superseded, nor than the kindred arts of dyeing and printing. In the instance of bleaching, the obligation due to the speculative chemist is universally felt and acknowledged. But the dyer and printer have yet to receive, from the philosopher, some splendid invention, which shall command their respect, and excite their attention to chemical science. From purely speculative men, however, much less is to be expected than from men of enlightened experience, who endeavour to discover the design and reason of each step in the processes of their arts, and fit themselves for more effectual observation of particulars, by diligently possesing themselves of general truths.

The objects of inquiry, that present themselves to the dyer and printer, are of considerable number and importance. The preparation of goods for the reception of colouring matter; the application of the best bases, or means of fixing fugitive colours; the improvement of colouring ingredients themselves; and the means of rendering them permanent, so that they shall not be affected by soap, or by the accidental contact of acids, or other corrosive bodies; are amongst the subjects of chemical investigation. It is the business of the dyer, therefore, to become a chemist; and he may be assured, that, even if no brilliant discovery should be the reward of the acquistion, he will yet be better fitted by it for conducting common operations with certain and unvaried success.

Many other chemical arts might be mentioned; but enough, I trust, has been said, to evince the connection between practical ſkill and the possession of scientific knowledge. I shall now proceed to develop the plan, on which the following course of Lectures will be conducted.

So much has been said of the importance of chemistry in promoting the improvement of the arts, that the Lectures, which are now to to be delivered, may, perhaps, be expected to point out, in detail, all the practical uses that may be made of the doctrines of this science. Such, however, is not the purpose of the present course, which will be limited in its objects to the general principles of the science only, and their illustration by the most apposite facts. It would be a tedious and useless labour, to enter at present into all the minuteness of technical description; for, the mind requires to be well grounded in the general truths of a science, before it can successfully direct them to the advantage of the arts. Thus, before any proficiency can be made in the arts of navigation, tactics, surveying, &c. the general principles of mathematics must first be clearly apprehended. Just so in chemistry:—A full and accurate knowledge must be gained of its principles, before any practical benefits can result from the attainment; and to the artist, who attentively studies this science, many applications of its doctrines will occur, without their being specifically pointed out. At some future period, however, it will, perhaps, be the object of a distinct course of Lectures to trace the various useful applications of chemistry, especially in those arts that are most interesting from their connection with the manufactures of this town.

There are two methods of delivering the general doctrines of chemistry, and the facts connected with them. The one consists in a historical detail of the gradual progress of the science; and, in pursuing this plan, we follow the natural progress of the human mind, ascending from particular facts to the establishment of general truths. But a strong objection to its adoption is, that we are thus led into a minuteness of detail, that is ill suited to the plan of elementary lectures. In the other mode of arrangement, we neglect wholly the order of time in which facts were discovered, and class them under general divisions, so framed as to assist the mind in apprehending and retaining the almost infinite variety of particular truths. The latter method appears most eligible, and I shall begin, therefore, with the exposition of those principles, that are most extensively concerned in the production of chemical effects.

Attraction, or affinity, is the great cause of all chemical changes; and has, therefore, the first claim to attentive consideration. Next to that of attraction, the influence of heat over the forms and qualities of bodies is the most generally observed fact; and, as this is a power that often counteracts chemical affinity, there is the more propriety in contrasting the operations of the two. The phenomena and laws of heat will conduct, naturally, to the great source or reservoir of it, which will be traced to a class of bodies, agreeing, in many properties, with the air of our atmosphere, and called airs and gasses. These gasses, we shall find, consist partly of solid gravitating matter, and partly of an extremely subtile fluid, which impresses on our organs the sensation of heat, and is termed caloric. When the solid ingredients of these gasses, usually called their bases, combine together, or with other bodies, caloric is given out, and new compounds formed. And as the gaseous bases are, generally speaking, simple or elementary substances, the consideration of the gasses, in this early period of the course, will be strictly conformable to the plan of beginning with simple substances, and proceeding gradually to the more complex. In treating of compound substances, those will first come under our review, that are formed by the action of the gaseous bases on each other, as water and the alcalis. We shall then be prepared to understand the most remarkable qualities of various other elementary bodies, which qualities appear generally in their action on the gasses. Thus, for example, the most remarkable property of sulphur is its forming with the basis of oxygenous gas, the sulphuric acid, or oil of vitriol. As the acids are a very important class of the objects of chemistry, they will be introduced early in the course, and their effects will be exhibited and explained on the bodies, which may have been already described; reserving the display of their action on other substances till these come to be separately considered. In treating of the sulphuric acid, for example, its relation to water and the alcalis only will be then described; for, it would be unseasonable to detail its effects on metallic and earthy bodies before this class of substances has been specifically discussed.

Having dismissed the consideration of such elementary bodies as are distinguished by affording acids when combined with oxygen; of the properties of the acids thus generated; and of the compounds afforded by the union of acids with alcalis; two interesting divisions of elementary substances will next claim our attention, viz. the earths and the metals. In the introduction of the earths before the metals I have been influenced by reflecting, that the natural history of the latter, of which it will be proper to present a general view, cannot be well understood, till that of the earths has been fully developed.

The more complex productions of the vegetable and animal kingdoms will be the next step in our progress through the science. The economy of the vegetable tribes has, of late years, received so much elucidation from chemistry, that it would be unpardonable to omit an account of the functions and productions of vegetable life, especially as this is a subject of extensive utility, from its connection with agricultural improvement. The course will be concluded by a view of the chemistry of the animal creation, and of the beautiful connection and subserviency to each other of the vegetable and animal kingdoms.

For the exclusive adoption of the new doctrines of chemistry, and of the nomenclature connected with them, no apology is necessary. Every one, who will be at the pains of attentively comparing the new with the old theory, I can venture to predict, will prefer the lucid arrangements and precision of the former to the confused order and illogical inferences of the phlogistic sect. From those who have been in the habit of teaching chemistry, both before and since the revolution in this science, we have the strongest testimony, that the labour of acquiring a knowledge of it is diminished beyond all comparison. — "I have adopted the new nomenclature," says Mr Chaptal, "in my lectures and writings, and I have not failed to perceive how very advantageous it is to the teacher; how much it relieves the memory; how greatly it tends to produce a taſte for chemistry; and with what facility and precision the ideas and principles concerning the nature of bodies fix themselves in the minds of the auditors." We have the approbation, also, of the most distinguished metaphysicians of the age, of the connection of new doctrines with a new and more accurate language. "The new nomenclature of chemistry," it is observed by Mr Dugald Stewart, in his Elements of the Philosophy of the Human Mind, "seems to furnish a striking illustration of the effect of appropriate and well defined expressions, in aiding the intellectual powers, and the period is probably not far distant, when similar innovations will be attempted in other sciences."

These doctrines, and the nomenclature dependent on them, have not, it muſt be acknowleged, been long established; and though the progress of chemistry, during and since their development, has advanced with unexampled rapidity, we should still so limit our approbation as not to eſteem them beyond the reach of improvement. — For my own part, I adopt them, not from a belief that they are perfect, but because they are better adapted, than any hitherto offered, for explaining and classing phenomena, and with this qualification I strongly recommend them to general acceptance.

A

CONCISE EPITOME

OF

CHEMISTRY.

PART I. — SECTION I.

Advice to Persons who are entering on the Study of Chemistry

THE few suggestions which I am about to offer, are addressed peculiarly to those who have not the opportunity of attending chemical lectures; and who have no means of acquiring a knowledge of chemistry, except from books, and from the evidence of experiments.

The principal difficulty experienced by all who embark in a scientific pursuit, unaided by the advice of an instructor, is the attainment of the best adapted books. In Chemistry, fortunately, this difficulty is limited to selection only: for we have, in the English language, many elementary works, both original and translated, of great merit. I shall, at present, however, confine myself to the mention of very few; of such only as are sufficient to convey, to a person of tolerable understanding and competent education, a general acquaintance with chemical science; and I shall afterward subjoin a list of other books, necessary to those who intend to pursue the study more extensively.

Of all the introductory treatises on Chemistry, that of Mr Lavoisier is certainly the one from which a person, entering, for the first time, on this study, will derive most pleasure and advantage. The first part of this work, comprehending the more general doctrines of Chemistry, should be perused with attention, and clearly understood, before the reader proceeds any farther. It may even be necessary, that, previously to the remainder of this work, he should study other elementary books, such as those of Chaptal, Fourcroy, Nicholson, and Thomson*. These works will supply the deficiencies of Lavoisier's Elements, especially on the subject of chemical affinity, the divisions and laws of which are essential to be known, as the ground-work of all chemical explanations. After having made himself master of the more general truths of Chemistry, as delivered in the first part of Lavoisier's, and in the first volume of Chaptal's, Elements, and also of the principles of the new nomenclature, the student will be qualified to reap advantage from the performance of experiments. In repeating these, he may either follow the order which I shall presently point out, or he may assume, as the basis of his arrangement, the general propositions laid down by Chaptal or Fourcroy, referring to the following section, for more minute and specific directions.

In the conducting of experiments, I would recommend great attention to neatness and to order. Let every jar or vial have a label affixed to it, denoting the substances it may contain, (except in cases where the

---

* Dr. Thomson's "System of Chemistry" is the work to which I refer. See the List of Elementary Books at the end.

nature of the contents is evident from mere inspection,) and the date and object of the experiment. I would caution the student, not to engage in many different experiments at once; the consequences of which are, that the attention is distracted, and that many interesting changes pass unnoticed. It will contribute to form a habit of accurate observation, if the appearances that occur in experiments be regularly and distinctly noted down; and such an exercise will tend also to facilitate the acquirement of the art of describing chemical phenomena; to do which, with selection and precision, is far from being a universal talent.

In advising an attention to neatness, however, I by no means recommend a frivolous regard to show, or even too scrupulous a nicety about the appearance of apparatus. With the aid merely of Florence flasks, of common vials, and of wine glasses, some of the most interesting and useful experiments may be made; and, in converting these vessels to the purpose of apparatus, a considerable saving of expense will accrue to the experimentalist.

SECTION II.

An arranged Series of Experiments, which should, either Wholly or in Part, be performed by the Student of Chemistry.

IN the selection of these experiments, I shall generally choose such as may be undertaken by persons not possessed of an extensive chemical apparatus. On some occasions, however, it may be necessary, in order to complete the series, that others should be included, requiring, for their performance, instruments of considerable nicety. The same experiment may, perhaps, in a few instances, be repeatedly introduced, in illustration of different principles; but this repetition will be avoided as much as possible. Each experiment will be preceded by a brief enunciation of the general truth which it is intended to illustrate.

ART. I. — *Chemical Affinity, Solution, &c.*

For these experiments, a few wine glasses, or, in preference, deep ale glasses, will be required, and a Florence flask for performing the solutions.

1. *Some bodies have no affinity for each other.* Oil and water, or mercury and water, when shaken together, do not combine, the oil or water always rising to the surface, and the mercury sinking to the bottom.

2. *Examples of solution.* Sugar or common salt in water; chalk in dilute muriatic acid*.

3. *Influence of mechanical division in promoting the action of chemical affinity, or in favouring solution.* Lumps of chalk or marble dissolve much more slowly in dilute muriatic acid, than equal weights of the same bodies in powder. In the common arts of life, the rasping and grinding of wood and other substances are familiar examples.

4. *Hot liquids are more powerful solvents than cold ones.* To four ounce measures of water, at the temperature of the atmosphere, add three ounces of sulphate of soda in powder. Only part of the salt will be dissolved, even after being agitated some time. Apply

---

* I omit, purposely, the distinction between solution and dissolution.

heat, and the whole of the salt will disappear. When the liquor cools, a portion of salt will separate again in a regular form. This last appearance affords an instance of *crystallization.*

5. *A very minute division of bodies is effected by solution.* Dissolve two grains of sulphate of iron in a quart of water, and add a few drops of this solution to a wine glass full of water, into which a few drops of tincture of galls have been fallen. The dilute infusion of galls will speedily assume a purplish hue. This shows that every drop of the quart of water, in which the sulphate of iron was dissolved, contains a notable portion of the salt.

6. *Some bodies dissolve much more readily and copiously than others.* Thus an ounce measure of distilled water will dissolve one third its weight of sulphate of soda; one sixteenth of sulphate of potash; and only one five-hundredth its weight of sulphate of lime.

7. *Mechanical agitation facilitates solution.* Into a wine glass full of water, tinged blue with the infusion of litmus, let fall a small lump of solid tartarous acid. The acid, if left at rest, even during some hours, will only change to red that portion of the infusion which is in immediate contact with it. Stir the liquor, and the whole will immediately become red.

8. *Bodies do not act on each other, unless either one or both be in a state of solution.* A. Mix some dry acid of tartar with dry carbonate of potash. No combination will ensue till water is added, which, acting the part of a solvent, promotes the union of the acid and alcali, as appears from the violent effervescence.

B. Spread thinly, on a piece of tinfoil, three or four inches square, some dry nitrate of copper*, and wrap it up. No effect will follow. Unfold the tinfoil, and, having sprinkled the nitrate of copper with very little water, wrap it up again as quickly as possible, pressing down the edges closely. Considerable heat, attended with fumes, will now be excited; and, if the experiment has been dexterously managed, even light will be evolved. This shows that nitrate of copper has no action on tin, till in a state of solution.

9. *Two bodies, having no affinity for each other, unite by the intervention of a third.* Thus, the oil and water which, in Expt 1st, could not, by agitation, be brought into union, unite immediately on adding a little solution of caustic potash. The alcali, in this case, acts as an intermedium.

10. *Saturation illustrated.* Water, after having taken up as much common salt as it can dissolve, is said to be saturated with salt. Muriatic acid, when it has ceased to act any longer on lime, is said to be saturated.

11. *The properties characterizing bodies when separate are destroyed by chemical combination.* Thus, muriatic acid and lime, which, in a separate state, have each a most corrosive taste, lose this entirely when mutually saturated; the compound is extremely soluble, though lime itself is very difficult of solution; the acid no

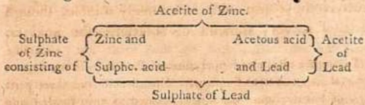
---

* To prepare nitrate of copper, dissolve the filings or turnings of that metal in a mixture of one part nitrous acid and three parts water; decant the liquor when it has ceased to emit fumes; and evaporate it to dryness, in a copper or earthen dish. The dry mass must be kept in a bottle.

longer reddens sirup of violets; nor does the lime change it, as before, to green.

12. *Simple elective affinity illustrated.* (A) Add to the combination of oil with alcali, formed in Expt 9th, a little dilute sulphuric acid. The acid will seize the alcali, and set the oil at liberty, which will rise to the top. In this instance, the affinity of alcali for acid is greater than that of alcali for oil. (B) To a dilute solution of muriate of lime, (prepared in Expt 2d,) add a little of the solution of pure potash. The potash will seize the muriatic acid, and the lime will fall down, or be *precipitated.*

13. *Double elective affinity exemplified.* In a watery solution of sulphate of zinc, immerse a thin sheet of lead. The lead will remain unaltered, as will also the sulphate of zinc; because zinc attracts sulphuric acid more strongly than lead. But let acetite of lead be mixed with sulphate of zinc. The lead will then go over to the sulphuric acid, while the zinc passes to the acetous. The sulphate of lead, being insoluble, will fall down in the state of a white powder; but the acetite of zinc will remain in solution. The changes that occur in this experiment will be better understood from the following scheme.



The vertical brackets include the original compounds viz. sulphate of zinc, and acetite of lead; and the horizontal brackets point out the new ones, viz. acetite of zinc and sulphate of lead. By the point of the bracket turning upwards, it is denoted, that the acetite of zinc remains in solution; and, by that of the lower one being directed downwards, it is meant to express, that the sulphate of lead falls down, or is precipitated. In cases of double decomposition, where both substances are precipitated, they are both placed beneath the lower bracket; and, when both remain in solution, above the upper one.

ART. II. — *Properties and Effects of the Matter of Heat, or Caloric**.

Effects of Caloric of Temperature, or uncombined Caloric.

1. *Caloric expands all bodies.* (A) The expansion of liquids is shown by that of the mercury of a thermometer. (B) That of the aërifrom bodies, by holding, near the fire, a bladder partly filled with air, the neck of which is closely tied, so as to prevent the enclosed air from escaping. The bladder will soon be fully distended, and may even be burst by continuing and increasing the heat. (C) The expansion of solids is shown, by heating a rod of iron, of such a length as to be included, when cold, between two points, and the diameter of which is

---

* I omit giving a connected series of experiments on Light, because the effects produced by this agent are, generally speaking, more complicated than those of Caloric. Thus, for example, the action of light frequently depends on its property of deoxidating bodies; and facts of this kind cannot be understood, without an acquaintance with the class of metallic oxyds. In the progress of this section, however, many instances will be given of the chemical efficiency of Light.

such, as barely to allow it to pass through an iron ring. When heated, it will have become sensibly longer; and it will be found incapable of passing through the ring.

All the above bodies return again, on cooling, to their former dimensions.

2. *Constructions of the thermometer founded on the principle of expansion.* For an excellent account of the method of constructing thermometers, which is too long to be inserted in this place, see Nicholson's Principles of Chemistry, Book 1st, chapter 3d.

3. *Equal increments or decrements of heat produce equal increments or decrements of expansion in the mercury of the thermometer.* Mix a pound of water, at 172°, with a pound at 32°. Half the excess of the uncombined Caloric, in the hot water, will pass to the colder portion; that is, the hot water will be cooled 70°, and the cold will receive 70° of temperature; therefore, 172—70, or 32+70, = 102, will give the heat of the mixture. To attain the arithmetical mean, exactly, several precautions, however, must be observed. (See Crawford on Animal Heat, p. 95. &c.)

4. *Uncombined caloric has a tendency to an equilibrium.* Any number of different bodies, at various temperatures, if placed under similar circumstances of exposure, all acquire a common temperature. Thus, if in an atmosphere at 60°, we place iron filings heated to redness, boiling water, and various other bodies of different temperatures, they will soon affect the thermometer in the same degree.

5. *Power inherent in bodies of conducting Caloric; and the conducting power various in different bodies.*

A. Solid bodies convey heat in all directions, upwards, downwards, and laterally; as may be shown by heating one end of an iron rod, and holding it in different directions.

B. Some bodies conduct caloric much more quickly than others. Coat two rods, of equal length and thickness, the one of glass, the other of iron, with wax, at one end of each only; and then apply heat to the uncoated ends. The wax will be melted much sooner from the end of the iron rod, than from the glass one; which shows, that iron conducts heat more quickly than glass.

C. Liquid and aëriform bodies convey heat on a different principle from that observed in solids, viz. by an actual change in the situation of their particles. Take a glass tube, eight or ten inches long, and about an inch in diameter. Pour into the bottom part, for about the depth of an inch, a little water tinged with litmus, and then fill up the tube with common water, pouring on the latter extremely gently, so as to keep the two strata quite distinct. When the tube is heated at the bottom, the cold infusion will ascend, and will tinge the whole mass. But, if the upper part of the tube be heated, the coloured liquor will remain at the bottom. Other experiments, illustrating the same principle, may be found in Count Rumford's Essays; especially in Essay 7th*. Thus a cake of ice will

---

* It is by no means decided, by Count Rumford's experiments, whether water be or be not an absolute nonconductor of heat. The reader who wishes to examine the objections and experiments that have been urged against the Count's theory, may consult the papers of Dr Thomson and Mr Murray, in Nicholson's Journal,

remain unmelted, during several hours, when confined at the bottom of a jar of hot water, which, if fixed at the surface, would be liquefied in a few minutes; and water may even be kept boiling, a considerable time, in a glass tube, over ice, without melting it.

5. *The boiling point differs in various liquors.* Thus Ether boils at 104°, Alcohol at 182°, and water at 212°. It varies, also, in the same liquor, under different degrees of atmospheric pressure. Thus water will boil, under the exhausted receiver of an air pump, at 180°, or even much less, of Faht; as may be proved by placing water, which has been removed from the fire and ceased to boil, under the receiver of an air pump, when, on exhausting the air, the ebullition will be renewed. The same fact may be proved by the following simple experiment: place, over a lamp, a Florence flask about ¾ filled with water; let it boil briskly, during a few minutes; and, immediately on removing it from the lamp, cork it tightly up. The water will now cease to boil; but, on cooling the upper part of the flask by a wet cloth, the boiling will be renewed. This renewal of the ebullition, by the application of cold, (an apparent paradox), is owing to the formation of an imperfect vacuum over the hot water, by the condensation of the steam. Hence the particles of Caloric are mutually repulsive, and they communicate this repulsive tendency to other bodies in which Caloric is contained. This repulsive power tends to change solids into fluids, and liquids into

4to, vol. iv and v, and in the 1st. vol. of the 8vo series of the same work.

aëriform bodies, and is chiefly counteracted by the pressure of the atmosphere. See some beautiful experiments, illustrating this position, in Lavoisier's Elements, chap. 1; and also the experiments in page 20 of this Epitome.

On the contrary, by considerably increasing the pressure, water may be heated to above 400°, without being changed into vapour*.

6. *Uncombined Caloric promotes the action of chemical affinity.* Thus lead and tin do not combine, till melted together. In other instances, Caloric serves as the mean of separating bodies already united. Thus lead and sulphur are disunited by exposure in a high temperature. In favouring the operation of affinity, Caloric seems to act as a solvent; and, in decomposing bodies, its effects are perhaps explicable on the principle of elective affinity. Thus, in the foregoing example, sulphur, in a high temperature, or when surrounded by a great quantity of uncombined caloric, is more powerfully attracted by caloric than by lead.

Combinations of Caloric — The Cause of Fluidity.

7. *The sensible heat, or temperature, of ice, not changed by liquefaction.* A thermometer in pounded ice stands at 32°, and at the very same point in the water, which results from the liquefaction of ice.

8. *Yet the ice, during liquefaction, must absorb much caloric.* Expose a pound of water at 32°, and a pound of ice at 32°, in a room, the temperature of which is several degrees above the freezing point, and uniformly

---

* To effect this, a strong iron vessel, called a digester, is necessary.

the same during the experiment. The water will arrive at the temperature of the room, several hours before the ice is melted; and the melted ice will give, as before its liquefaction, the temperature of 32°. Yet the ice must, during the whole of this time, have been receiving caloric, because, according to expt. 4, a hotter body can never be in contact with a colder one, without imparting heat to the latter. The caloric, therefore, which has entered the ice, but is not to be found in it by the thermometer, must be chemically combined; just as muriatic acid, by union with lime, loses all its characteristic properties.

9. *The quantity of uncombined caloric that enters into a pound of ice, and becomes united, during liquefaction, may be learned by experiment.* To a pound of water, at 172°, add a pound of ice at 32°. The temperature will not be the arithmetical mean, as in expt. 6, but much below it, viz. 32°. All the uncombined caloric of the hot water has, therefore, disappeared. From 172°, take 32°; the remainder, 140, shows the quantity of caloric that combines with a pound of ice, during liquefaction; that is, as much caloric is absorbed by, and unites chemically with, a pound of ice, during its conversion into water, as would raise a pound of water from 32° to 172°.

Other examples of the absorption of caloric, during the liquefaction of bodies, are furnished by the mixture of snow and nitric acid, or of snow and common salt, both of which, in common language, produce intense cold *. Most neutral salts, also,

---

* The extraordinary powers of muriate of lime and snow, in generating cold, will be described hereafter.

during solution in water, absorb much caloric, and the cold thus generated is so intense as to freeze water, and even to congeal mercury. The former experiment, however, (viz. the congelation of water,) may easily be repeated on a summer's day. Add to 32 drachms of water, 11 drachms of muriate of ammonia; 10 of nitrate of potash; and 16 of sulphate of soda; all finely powdered. The salts may be dissolved, separately, in the order set down. A thermometer, put into the solution, will show that the cold produced is at or below freezing; and a little water, in a thin glass tube, being immersed in the solution, will be frozen in a few minutes. Various other freezing mixtures are described in Mr Walker's papers in the Philosophical Transactions for 1787, 88, 89, 95, and 1801.

10. *On the contrary, liquids, in becoming solid, evolve or give out caloric, or, in common language, produce heat.*

A. Water, if kept perfectly free from agitation, may be cooled down below 32°; but, on shaking it, it immediately congeals, and the temperature rises to 32°.

B. Expose water to the air, when at 20° of Faht. or thereabouts. The water will remain, some time, stationary at 32°, during which it must be giving out heat to the atmosphere. The heat, thus evolved, is that which constituted the fluidity of the water. This experiment is the converse of No. 8.

C. To a saturated solution of sulphate of potash in water, or of any salt that is insoluble in alcohol, add an equal measure of alcohol. The alcohol, attracting the water more strongly than the salt retains it, precipitates the salt, and considerable heat is produced.

Caloric the Cause of Vapour.

11. *Steam has exactly the same temperature as boiling water.* Let a tin vessel be provided, having a hole in its cover, just large enough to admit a thermometer. Fill it partly with water, and let the bulb of the thermometer be an inch or two above the surface of the water. When the water boils, the thermometer, surrounded by steam, will rise to 212°, which is precisely the temperature of the water beneath. Yet water, placed on a fire, continues to receive heat, very abundantly, even when boiling hot; and as this heat is not appreciable by the thermometer, it must exist in the steam, in a state of chemical union.

12. *The absorption of caloric, during evaporation, shown by experiment.*

Moisten a thermometer with alchohol, or with ether, and expose it to the air, repeating these operations alternately. The mercury of the thermometer will sink at each exposure, because the volatile liquor, during evaporation, robs it of its heat. In this way, (especially with the aid of an apparatus described by Mr Cavallo, in the Phil. Trans. for 1781, p. 509,) water may be frozen in a thin and small glass ball, by means of ether; and also by immersing a tube, containing water at the bottom, in a glass of ether, placed under the receiver of an air pump; or the ether may be allowed to float on the surface of the water. During the exhaustion of the vessel, the ether will evaporate rapidly; and, robbing the water of heat, will completely freeze it.

13. *On the contrary, vapours, during their conversion into a liquid form, evolve, or give out, much caloric.* The

heat given out, by the condensation of steam, is rendered apparent by the following experiment. Mix 100 gallons of water, at 50°, with one gallon of water at 212° *. The temperature of the water will be raised about 1½ degree. Condense, by a common still-tub, one gallon of water, from the state of steam, by 100 gallons of water, at the temperature of 50°. The water will be raised 11 degrees. Hence, eight pounds of water, condensed from steam, raise 100 gallons of cold water, 9½ degrees more than eight pounds of boiling water; and, by an easy calculation, it appears, that the caloric imparted to the hundred gallons by the steam, if it could be condensed in one gallon of water, would raise it to 950°. A pound of water, therefore, in the state of steam, contains more caloric than a pound of boiling water, in the proportion of 950 to 212.

ART. III. — *Gasses in General.*

For performing the necessary experiments on gasses, many articles of apparatus are essential that cannot be included in a portable chemical chest; which may yet, however, contain the materials for procuring gasses. It may assist the student in obtaining the necessary instruments, if a few of the most essential be here enumerated. I shall mention none, however, except such as are necessary in making a few general experiments on this interesting class of bodies.

The apparatus, required for experiments on gasses, consists partly of vessels fitted for containing the materials that afford them; and partly of vessels adapted for

---

* This experiment will be equally conclusive, if repeated on a smaller scale.

the reception of gasses, and for submitting them to experiment.

1. For procuring such gasses as are producible without a very strong heat, glass bottles, furnished with ground stoppers and bent tubes, are sufficient. Of these several will be required, of different sizes and shapes, adapted to different purposes. If these cannot be procured, a Florence flask, with a cork perforated by a bent glass tube, or even a tin pipe, will serve for obtaining some of the gasses.

Those gasses that require for their liberation a red heat, may be procured by exposing to heat the substance, capable of affording them, in earthen retorts or tubes *; or in a gun barrel, the touch-hole of which has been accurately closed by an iron pin. To the mouth of the barrel must be affixed a glass tube, bent so as to convey the gasses wherever it may be requisite.

2. For receiving the gasses, glass jars, of various sizes, are required, some of which should be furnished with necks at the top, fitted with ground stoppers. These jars will also be found extremely useful in experiments on the properties and effects of the gasses. Some of them should be graduated into cubical inches.

To contain these jars, when in use, a vessel will be necessary, capable of holding a few gallons of water. This may either be of wood, if of considerable size; or, if small, of tin, japanned or painted. Its size may vary

---

* Very compact earthen retorts and tubes are made by Messrs Wedgwoods and Byerly, of Etruria. Others also, less close in their texture, but less apt to break in the use, may be had of Messrs Pugh and Speck, of Booth Street, Spitalfields, London, who make portable furnaces, crucibles, &c.

with that of the jars employed; and, about half an inch from the top, it should have a shelf, on which the jars may be placed, when filled with air, without the risk of being overset.

A glass tube, about 18 inches long, and three-quarters of an inch diameter, closed at one end, and divided into cubic inches and tenths of inches, will be required for ascertaining the purity of air by nitrous gas. It should be accompanied also with a small measure, containing about two cubic inches, and similarly graduated. For employing the solution of nitrous gas in liquid sulphate of iron, (a happy invention of Mr Davy, which leaves nothing to be desired in eudiometry,) glass tubes, about five inches long, and half an inch wide, divided decimally, are also necessary. Besides these, the experimenter should be furnished with air funnels, for transferring gasses from wide to narrow vessels. These, and almost every other article of apparatus, necessary for experiments on gasses, may be seen figured in the plates to Dr Priestley's Experiments on Air, in 3 vols 8vo; and in those subjoined to Lavoisier's Elements.

For those gasses that are absorbed by water, a mercurial trough is necessary. For the mere exhibition of a few experiments on these condensible gasses, a small wooden trough, 11 inches long, 2 wide, and 2 deep, cut out of a solid block of mahogany, is sufficient; but, for experiments of research, one of considerable size is required.

Previously to undertaking experiments on other gasses, it may be well for an unpractised experimentalist to accustom himself to the dexterous management of gasses, by transferring common air from one vessel to another, of different sizes.

Of experiments illustrative of the nature of gasses in general, it may be proper to mention one or two that show the mode in which caloric exists in this class of bodies. In vapours, strictly so called, as the steam of water, caloric seems to be retained with but little force; for it quits the water when the vapour is merely exposed to a lower temperature. But, in gasses, caloric is united by very forcible affinity, and no diminution of temperature, that has ever yet been effected, can separate it from some of them. Thus the air of our atmosphere, in the most intense artificial or natural cold, still remains in the aeriform state. Hence is derived one character of gasses, viz. that they shall remain aeriform, under almost all variations of pressure and temperature; and in this claſs are also included those aerial bodies which, being condensed by water, require confinement over mercury. The following experiment will show that the caloric, contained in gasses, is chemically combined.

Into a small retort, put an ounce or two of well dried common salt, and about half its weight of sulphuric acid. By this process, a great quantity of gas is produced, which might be received and collected over mercury. But, to serve the purpose of this experiment, let it pass through a glass balloon, having two openings (as in the 4th plate of Lavoisier, fig. 1. G.), into one of which the neck of the retort passes, while, from the other, a bent tube proceeds (E. of the same fig.) which ends in a vessel of water. Before closing the apparatus, let a thermometer be included in the balloon, to show the temperatnre of the gas. It will be found, that the mercury, in this thermometer, will rise only a few degrees, whereas the water, in the vessel which receives the bent tube, will soon become boiling hot. In this instance, caloric flows from the lamp to the muriatic acid, and converts it into gas; but the heat, thus expended, is not appreciable by the thermometer, and must, therefore, be chemically combined. The caloric, however, is again evolved, when the gas is condensed by water; and, in this experiment, we trace it into combination, and again into the state of uncombined caloric.

For demonstrating the influence of variations of atmospheric pressure on the formation of gasses, better experiments cannot be devised than those of Lavoisier. See his Elements, chap. 1. But as some students, who have the use of an air-pump, may not possess the apparatus described by Lavoisier, (the glass bell and sliding wire,) it may be proper to point out an easier mode of showing the same fact. Into a glass tube, about six inches long, and half an inch diameter, sealed at one end, put a small quantity of ether; and fill the tube with water, tinged blue by litmus. The ether will swim on the surface of the water. Place the thumb, expeditiously, over the open end of the tube, so as to confine the water and ether, without including any air along with them; and set the tube, inverted, in a jar of coloured water; removing the thumb, when this has been effected. When the above apparatus is covered with the receiver of an air-pump, and the air is exhausted, the ether will be changed into a gas, which will fill the tube and expel the water. On restoring the pressure of the atmosphere, the ether will again become liquid.

ART. IV. — *Oxygenous Gas.*

1. *Oxygenous gas may be procured from various substances.*

A. From the black oxyd of manganese, heated to redness in a gun barrel, or earthen retort; or, from the same oxyd, heated by a lamp in a retort or gas bottle, with half its weight of strong sulphuric acid.

B. From the red oxyd of lead (the common red lead used by painters) heated either with or without sulphuric acid.

C. From various other oxyds, as will be hereafter mentioned.

D. From nitrate of potash (common saltpetre) made red hot in a gun barrel, or in an earthen retort.

E. From oxygenated muriate of potash, heated in a small glass retort, coated with clay; or in an earthen retort. The oxygenous gas, thus produced, is much purer than that obtained in any other mode, especially the last portions, which should be kept separate.

This gas has the following properties:

2. *It is not absorbed by water*, or, at least, is so sparingly absorbed, that, when agitated in contact with water, no perceptible diminution takes place.

3. *All combustible bodies burn in oxygenous gas with greatly increased splendor.*

A. A lighted wax taper, fixed to an iron wire, and let down into a vessel of this gas, burns with great brilliancy. (See Lavoisier's 5th plate, fig. 8.) If the taper be blown out, and let down into a vessel of the gas, while the snuff remains red hot, it instantly rekindles, with a slight explosion.

B. A red hot bit of charcoal, fastened to an iron wire, and immersed in the gas, throws out beautiful sparks.

C. The light of phosphorus, placed on a little tin cup, and burnt in this gas, is the brightest that can be in any mode produced.

D. Procure some thin harpsichord wire, and twist it round a slender rod of iron or glass, so as to coil it up in a spiral form. Then withdraw the rod, and tie a little thread, or flax, round one end of the wire, for about the length of one-twentieth of an inch, which end is to be dipped into melted sulphur. The other end of the wire is to be fixed into a cork; so that the spiral may hang vertically. Fill, also, with oxygenous gas, a bottle capable of holding about a quart, and set it with its mouth upwards. Then light the sulphur, and introduce the wire into the bottle of gas, suspending it by the cork. The iron will burn with a most brilliant light, throwing out a number of sparks, which fall to the bottom of the bottle, and generally break it. This accident, however, may frequently be prevented by pouring sand into the bottle, so as to lie about half an inch deep on the bottom. (See Lavoisier's 4th plate, fig. 17.) According to Mr Accum (Nicholson's Journal, 8vo, i. 320) a thick piece of iron or steel, such as a file, if made sharp pointed, may be burnt in oxygen gas. A small bit of wood is to be stuck upon its extremity, and set on fire, previous to immersion in the gas.

E. A little of Homberg's pyrophorus, a substance to be hereafter described, when poured into this gas, immediately flashes like inflamed gun-powder.

4. *During every combustion in oxygenous gas, the gas suffers a material diminution.* To exhibit this, experimentally, in a manner perfectly free from all sources of error, would require such an apparatus as few persons are likely to possess. The apparatus required, may be seen described in the 6th chapter of Lavoisier's Elements. The fact may, however, be shown, less accurately, in the following manner. Fill, with oxygenous gas, a jar, of moderate size, which has a neck and ground glass stopper at the top. Then, with the assistance of a stand, formed of bent iron wire, (like that shown in the plate to Nicholson's Chemistry, fig. 16,) place a shallow tin vessel, containing a bit of phosphorus or sulphur, three or four inches above the level of the water of a pneumatic trough. Invert the jar of oxygenous gas, cautiously and expeditiously, over this cup, so as to confine it, with its contents, in the gas, and, pressing down the jar to the bottom of the trough, open the stopper. A quantity of gas will immediately rush out, and the water will rise to the same level within the jar as without. When this has taken place, set fire to the sulphur or phosphorus by an iron wire, and instantly put in the stopper. The first effect of the combustion will be a depression of the water within the jar; but, when the combustion has closed, and the vessel has cooled, a considerable absorption will be found to have ensued.

5. *All bodies, by combustion in oxygenous gas, acquire an addition to their weight; and the increase is in propor-*

tion to the quantity of gas absorbed. To prove this by experiment, requires also a complicated apparatus; and the reader, who cannot possess himself of this, must remain satisfied with the account Lavoisier gives of his experiments, establishing the principle, in chapter 5th of his Elements.

6. *Oxygenous gas supports, eminently, animal life.* It will be found that a mouse, bird, or other small animal, will live six times longer in a vessel of oxygenous gas, than in one of atmospherical air of the same dimensions.

7. *This effect seems connected with the absorption of oxygen by the blood.* Pass up a little dark coloured blood into a jar partly filled with oxygen gas, and standing over mercury. The gas will in part be absorbed, and the colour of the blood will be changed to a bright and florid red. This change to red may be shown by putting a little blood into a common vial filled with oxygenous gas, and shaking it up.

ART. V. — *Azotic or Nitrogen Gas.*

1. Azotic Gas may be procured, though not absolutely pure, yet sufficiently so for the purpose of exhibiting its general properties, in the following manner. Mix equal weights of iron filings and sulphur into a paste with water, and place the mixture, in a proper vessel, over water, on a stand similar to that described, Art. IV. No. 4. Then invert over it a jar full of common air, and allow this to stand exposed to the mixture for a day or two. The air contained in the jar will gradually diminish, as will appear from the ascent of the water within the jar, till at last only about three-fourths of its original bulk remain. The vessel containing the iron

and sulphur, must next be removed, by withdrawing it through the water; and the remaining air may be made the subject of experiment.

A quicker process for procuring azotic gas consists in filling a bottle, about one fourth, with the solution of nitrous gas, in liquid sulphate of iron, and agitating it with the air, which fills the rest of the bottle. During the agitation, the thumb must be placed firmly over the mouth of the bottle; and, when removed, the mouth must be immersed in a cup full of the same solution, which will supply the place of the absorbed air.

2. This gas has the following properties:

A. It is not absorbed by water.

B. It immediately extinguishes a lighted candle and all other burning substances.

C. It is fatal to animals that are confined in it.

D. Plants, however, live in it, and even flourish.

E. When mixed with pure oxygenous gas, in the proportion of three or four parts to one of the latter, it composes a mixture resembling atmospheric air in all its properties. Of this any one may be satisfied, by mixing three parts of azotic gas with one of oxygenous gas; and immersing in the mixture a lighted taper. The taper will burn as in atmospherical air.

Art. VI. — *Atmospheric Air.*

The air of our atmosphere, it appears, therefore, from the foregoing facts, is a mixture, or rather a combination, of two different gasses, viz. oxygenons gas and azotic gas. The former of these two seems to be the only ingredient on which the effects of the air, as a chemical agent, depend. Hence combustible bodies burn in atmospheric air, only in consequence of the oxygenous gas which it contains; and, when this is exhausted, air is no longer capable of supporting combustion*. The abstraction of its oxygenous gas from the air will be rendered apparent by the following experiments.

1. Burn a little sulphur or phosphorus, in the manner described, Art. IV. No. 4. substituting for oxygenous gas common atmospherical air. The combustion will in this instance be less vivid; will cease sooner; and the absorption, when the vessels have cooled, will be much less considerable than in the former case.

2. Take two tubes, each a few inches long, closed at one end, and divided into aliquot parts. Fill the one with atmospherical air, the other with oxygenous gas, and invert them in two separate cups filled with a solution of sulphuret of pot-ash. The sulphuret will ascend gradually within the tube of common air, till, after a few days, only about three-fourths of its original volume will remain: but, in that containing oxygenous, it will ascend much higher; and, if the gas be pure, will even absorb the whole. The explanation of this fact is, that liquid sulphuret of pot-ash has the property of absorbing oxygen, but not azote. It therefore acts in atmospheric air only as long as any oxygenous gas remains, and may be employed as a means of ascertaining the quantity of this gas in the amosphere at different

---

* Certain combustible bodies even cease to burn in atmospheric air, long before its oxygenous portion is consumed; for reasons that will hereafter be given.

times, and in distant places. An improved instrument, thus graduated, has lately been employed by Guyton as an *Eudiometer**. (See Nicholson's Philosophical Journal, Vol. I. page 268; or Tilloch's Philosophical Magazine, Vol. III. p. 191.)

3. *Atmospheric air ministers to the support of animal life, only in consequence of the oxygenous gas which it contains.* Air, after having been received into the lungs, and again expired, is found to have lost considerably of its oxygenous part, viz. 10 or 12 per cent. It proves fatal to animals, however, long before the whole of this purer portion is wholly exhausted; and hence it appears that a considerable proportion of oxygenous gas is even necessary to fit the air for supporting respiration. As the analysis of expired air requires an acquaintance with another gas, not hitherto described, viz. carbonic acid, its examination will be postponed to a future occasion.

ART. VII. — *Hydrogenous Gas.*

1. *To procure hydrogenous gas,* let sulphuric acid, previously diluted with five or six times its weight of water, be poured on iron filings, or on small iron nails, in a gas bottle or small retort. An effervescence will ensue, and the escaping gas may be collected in the usual manner:

This gas has the following properties:

2. *It remains permanent over water,* or is not absorbed in any notable proportion.

3. *It is inflammable.* This may be shown by the following experiments.

---

* Other Eudiometers will be described hereafter.

A. Fill a small jar with the gas, and, holding it with the mouth downwards, bring the gas into contact with the flame of a candle. The air will take fire, and will burn silently with a lambent flame.

B. Fill with this gas a bladder which is furnished with a stop cock, and with a small pipe, of diameter less than that of a common tobacco pipe. Press the air out through the pipe, and, on presenting a lighted candle, the stream will take fire. If this apparatus cannot be procured, a very simple contrivance will answer the purpose. Break off part of an eight-ounce vial, within an inch or two from the bottom, by setting fire to a string tied round it, and moistened with spirit of turpentine. The vial will then resemble a jar with an open neck at the top. Next bore a small hole through a cork that fits the neck of the vial, and insert in it part of a common tobacco pipe, which may be fixed into the neck of the bottle, by a cement of resin and bees-wax. Then fill the bottle with water, and hold it, with the thumb pressed down on the aperture of the pipe, while hydrogenous gas is passed into it. When the bottle is full of gas remove the thumb, press the bottle down into the water, and, on the approach of a candle, the stream of air from the pipe will take fire. I prefer this mode of making the experiment to the common one of inflaming the gas, as it proceeds, through a a small tube, from the bottle in which it is produced; because I have once seen an explosion, and frequently heard of similar accidents, from the latter mode of making the experiment.

C. In a strong bottle, capable of holding about four ounces of water, mix equal parts of common air and hydrogenous gas. On applying a lighted candle the mixture will burn, not silently, as in expt. A, but with a sudden and loud explosion. If a larger bottle be used, it should be wrapped round with a handkerchief, to prevent the glass from doing any injury, in case the bottle should burst.

D. The same experiment may be repeated with oxygenous gas, instead of atmospherical air; changing the proportions, and mixing only one part of oxygenous gas with two of hydrogenous. The report will be considerably louder. The bottle should be a very strong one, and should be wrapped round with cloth, to prevent an accident *.

E. The same experiment may be made over water, by means of the electric spark. Procure a strong tube, about three quarters of an inch diameter, and 12 inches long, closed at one end. About a quarter or half an inch from the sealed end, let two small holes be drilled, opposite to each other, and into each of these let a brass conductor be cemented, so that the two points may be distant from each other, within the tube, about one eighth of an inch. Into this tube, standing over water, pass about a cubic inch, or less, of a mixture of hydrogenous and oxygenous gasses, in the proportion of two measures of the former to one of the latter. Hold the tube firmly, and pass an electric spark through the mixed gasses. An immediate explosion will take place; after which the gasses, if pure, and in the proper proportion, will be found to have disappeared entirely. If atmospheric air be used, the remaining gas will be found to be unfit for supporting combustion,

---

* These experiments may also be made advantageously, by means of an apparatus, sold under the name of the inflammable air pistol.

the hydrogenous gas having robbed it of all its oxygen. Hence, the inflammation of hydrogenous gas, in graduated tubes, has been employed as a means of measuring the purity of air, and is the principle of Volta's eudiometer.

F. The diminution of hydrogenous and oxygenous gasses, by the union of their bases, may be shown also by their slow combustion. Fill a tall jar with oxygenous gas, and fill also, with hydrogen gas, a bladder furnished with a stop cock, and with a long brass pipe, bent like the letter S, and drawn out to a fine point. On pressing the bladder, a stream of gas will issue from the pipe, which may be set fire to, and brought cautiously under the tall inverted jar of oxygenous gas. By this contrivance, the stream of hydrogen gas will be burnt in a confined portion of oxygen gas; and, on continuing the combustion a sufficient length of time, the water will be seen to rise gradually within the jar. On the first impression of the heat, indeed, a quantity of gas will escape from the jar, which will render it difficult to ascertain what degree of absorption has actually taken place. But this loss may be prevented by using a jar with a neck at the top, to which a compressed bladder is firmly tied. The expanded air, instead of escaping through the water, will now fill the bladder at the top; and, when the experiment has closed, and the vessels have cooled, it may be ascertained, by pressing out the gas from the bladder, what quantity of oxygen gas has been consumed.

When the above experiment is made, with the substitution of common air for oxygenous gas, a diminution takes place, but much less considerable; viz. not amounting to one sixth of the original bulk of the gas.

4. *Hydrogenous gas has an unpleasant smell.*

5. *Though inflammable itself, it extinguishes burning bodies.* Bring an inverted jar, filled with this gas, over the flame of a candle; and suddenly depress the jar, so that the lighted wick may be wholly surrounded by the gas. The candle will immediately be extinguished.

6. *It is fatal to animals.* This may be shown by confining, in the gas, a mouse, or other small animal.

7. *It is considerably lighter than atmospherical air.*

A. Let a jar, filled with this gas, stand, for a few seconds, with its open mouth upwards. On letting down a candle, the gas will be found to have escaped.

B. Place another jar of the gas inverted, or with its mouth downwards. The gas will now be found to remain in the jar, being prevented from escaping upwards by the bottom and sides of the vessel.

C. Fill, with hydrogen gas, a bladder furnished with a stop-cock; and adapt to this a common tobacco pipe. Dip the bowl of the pipe into a lather of soap, and, turning the cock, blow up the lather into bubbles. These bubbles, instead of falling to the ground, like those commonly blown by children, will rise rapidly into the air. On this property of hydrogen gas, is founded its application to the raising of balloons.

8. *Hydrogenous gas, though fatal to animal life, is not so to vegetables, which grow, and even flourish, in it.*

ART. VIII.—*Composition and Decomposition of Water.*

In Art. VII. (No. 3, E.) it was stated that oxygenous and hydrogenous gasses, when fired over water, in the proper proportion, wholly disappear. To ascertain the nature of the product thus formed, however, the experiment must be repeated over mercury, in a similar manner. When this is done repeatedly, it is found that the product of the combustion is that well known fluid, water, which is thus proved to be composed of two elementary ingredients. The water, produced in this mode, is not, however, to be considered as a compound of the two gasses, but only of their bases; for the light and caloric, which constituted the gasses, escape, in considerable part, during the combustion. Every gas, it must be remembered, has at least two ingredients; the one gravitating matter, which, if separate, would probably exist in a solid or liquid form; the other an extremely subtile fluid, termed caloric. In the example before us, caloric (and perhaps light) is a common ingredient both of hydrogen and oxygen gasses; but the two differ in having different bases. The basis of the one is called hydrogen, of the other, oxygen; and water may, therefore, be affirmed to be a compound of hydrogen and oxygen. This may be proved in two modes, by synthesis, i. e. by joining together its two elementary ingredients; and by analysis, in other words, by separating the constituent parts of water, and again exhibiting them in a distinct form.

1. *Synthetic Experiments.*

A. Fill, with hydrogen gas, a bladder, furnished with a stop-cock and bent pipe, similar to that described, Art. VII. No. 3, F. Then pour into a shallow earthern dish as much quicksilver as will about half fill it, and invert over this a glass bell full of common air and perfectly dry. Expel the hydrogen gas through the pipe; light the stream; and bring it under the glass bell, by raising this, and depressing it into the mercury, as soon as the inflamed gas is introduced. A portion of air will escape, at first, in consequence of the rarefaction. As the combustion continues, water will form, and will condense on the sides of the glass. This water is produced by the union of hydrogen with the oxygen contained in atmospheric air.

B. Those persons who are not possessed of a sufficient quantity of quicksilver to repeat the above experiment, may substitute the following: procure a large glass globe, capable of holding three or four quarts, and having two openings, opposite to each other, which may be drawn out for a short distance, like the neck of a retort. Inflame the stream of hydrogen gas, and introduce it into the centre of the globe. The rarified and vitiated air will ascend through the upper aperture of the globe, and a constant supply of fresh air will be furnished from beneath. By this combustion, a quantity of water will be generated, which will be condensed on the inner surface of the vessel.

C. A simple and ingenious apparatus, less costly than any other, intended for the purpose of exhibiting the composition of water, is made by Mr Cuthbertson, of London. It may be seen described and figured in Nicholson's Journal, Vol. II. p. 235; or in the Philosophical Magazine, Vol. II. p. 317.

D. Those persons who have the opportunity of repeating this interesting experiment on a large scale, and with an accurate attention to proportion, may consult Lavoisier's Elements.

E. By firing repeated portions of a mixture of oxygenous and hydrogenous gasses, over mercury, a sensible quantity of water will at last be produced.

2. *Analytic Experiments.*

The analytic experiments on water are of two kinds; 1st, such as present us with one of its ingredients only, in a separate and distinct form; 2dly, such as present us with its two component principles, the hydrogen and oxygen, mixed together in the state of gas.

Of the first kind are the following:

A. Procure a gun-barrel, the breech of which has been removed, so as to form a tube open at each end. Fill this with iron wire, coiled up in a spiral form. To one end of the barrel adapt a small glass retort, partly filled with water, and to the other a bent glass tube, the open end of which terminates under the shelf of the pneumato-chemical apparatus. Let the barrel be placed horizontally, (or rather with that end, to which the retort is fixed, a little elevated,) in a furnace having two openings in its body opposite to each other, or in a grate like that figured by Lavoisier, plate 7, figure 11. Light a fire in the furnace; and, when the gun-barrel has become red-hot, apply a lamp under the retort. The steam of the water will pass over the red hot iron, and will be decomposed. Its oxygen will unite with the iron; and its hydrogen will be obtained in the form of a gas. This is the readiest and cheapest mode of procuring hydrogen gas, when wanted in considerable quantity.

B. The same experiment may be repeated; substituting an earthern tube for a gun-barrel, and weighing the iron wire accurately, both before and after the experiment. The iron will be found to have gained weight very considerably; and, if attention be paid to the weight of the water that escapes decomposition, by an addition to the apparatus, similar to that employed by Lavoisier, (plate 7, fig. 11, S and H,) and to the weight of the gasses obtained, it will be found that the weight gained by the iron, added to that of the hydrogen gas, will make up exactly the weight of the water that has disappeared. From experiments of this kind, conducted with the utmost attention to accuracy, as well as from synthetic experiments, it appears that water is compounded of 85 per cent oxygen, and 15 hydrogen, by weight, very nearly. But as hydrogen gas is eleven times lighter than common air, the proportion of gasses, by volume, required to form water, is about two of hydrogen to one of oxygen gas.

C. Water may be decomposed, in a similar apparatus, over charcoal instead of iron. The results, however, are different in this case, as will appear from a subsequent section.

D. Another mode of effecting the decomposition of water yet remains to be mentioned, in which not the hydrogen but the oxygen is obtained in a gaseous state. This is by the action of living vegetables; either entire, or by means of their leaves only. Fill a clear glass globe with water, and put into it a number of green leaves, from almost any tree or plant. A sprig or two of mint will answer the purpose perfectly well. Invert the glass, and place it, with its mouth downwards, in a vessel of water. Expose the whole apparatus to the direct light of the sun, which will then fall on the leaves surrounded by water. Bubbles of air will soon begin to form on the leaves, and will increase in size, till at last they rise to the top of the vessel. This process may be carried on as long as the vegetable continues healthy; and the gas, when examined, will prove to be oxygenous gas nearly pure. In this experiment, the hydrogen combines with the plant, to the nourishment and support of which it contributes, while the oxygen is set at liberty.

2dly. The processes, by which the elementary parts of water are separated from each other, and both are presented in an aeriform state, as a mixture of hydrogen and oxygen gasses, are dependent on the agency of electricity.

A. The first of these experiments requires for its performance the aid of a powerful electrical machine. This fact was the discovery of a society of ingenious Dutch chemists; and the principal circumstance, in the experiment, is the transmission of electrical shocks, through a confined portion of water. The apparatus employed, in this experiment of Messrs Dieman and Van Troostwyk, is a glass tube, about one eighth of an inch diameter, and 12 inches long, one of the ends of which is sealed hermetically, a good wire being inserted at this end, and projecting about an inch and a half within the tube. About the distance of five eighths of an inch from the extremity of this, another wire is to be fixed, which may extend to the open end of the tube. The tube is next to be filled with distilled water, and to be placed inverted in a vessel of the same. When thus disposed, electrical shocks are to be passed between the two ends of the wire, through the water; and, if these shocks be sufficiently strong, bubbles of air will be formed at each explosion, and will ascend till the upper part of the wire is uncovered by the water. As soon as this is effected, the next shock that is passed will set fire to the air, and the water will rise again in the tube, a very small quantity of gas remaining. Now as hydrogen and oxygen gasses, in a state of admixture, are the only ones that are capable of inflaming by the electric shock; and as there is nothing in the tube, besides water, that can afford them in this experiment, we may safely infer, that the evolved hydrogen and oxygen gasses arise from decomposed water.

B. An improved apparatus, exhibiting the same experiment, with less trouble to the operator, has been invented by Mr Cuthbertson, and may be seen described and figured in Dr. Pearson's paper, in the Phil. Trans. for 1797, or in Nicholson's Journal, Vols I. and II.

C. The same experiment may be performed with the aid of an apparatus of great simplicity, and which it is in the power of almost any person to make for himself. This is the newly discovered pile of Signior Volta; a discovery which, for curiosity and importance, in a philosophical view, ranks with the first that have been made during the present century. It is constructed in the following manner:

Procure, at a brazier's or coppersmith's, 30, 40, or 50, pieces of zinc or speltre, cast in sand, of the size of half crowns or shillings, but rather thicker. A corresponding number of half crowns or shillings will also be required, according to the size of the pieces of zinc that may be employed. Let an equal number of pieces of woollen cloth be cut, of a circular shape, to correspond with the pieces of zinc; and steep these in a strong solution of common salt in water. Then dispose the three substances alternately, in the following order, silver, zinc, moistened cloth; silver, zinc, &c. till a sufficient number of these triplicates, not less than 20 or 30, have been thus arranged, the silver terminating the pile at the top. In order to facilitate the touching of the bottom piece of silver, it may be well to put under it a slip of tinfoil or Dutch leaf, which may project a few inches. Next, let the hands be moistened with salt and water, and, on touching the piece of tinfoil with one hand, and the uppermost piece of silver with the other, a shock will pass through the arms, which will be strong, in proportion to the number of pieces of zinc, &c. that are employed.

The silver and zinc plates may also be more commodiously arranged in a mahogany trough. When intended for this purpose, they must be cast in squares of about two inches and a half, and must be let down, and well cemented, into grooves cut in the wood. The two metals may be in contact, and may even be soldered together; and between each pair of plates a cell is to be left for containing the liquid to be employed. Troughs of this kind are much more powerful, and are kept in order with less trouble than the pile.

With this apparatus, the decomposition of water is effected with the utmost facility. Take a narrow glass tube 3 or 4 inches long; fit each end with a cork, penetrated by a piece of slender iron wire, and fill the tube with water. Let the ends of the two wires be distant from each other, about three-fourths of an inch; and let the one be made to communicate with the bottom of the pile, the other with the top. On making this communication, bubbles of air will form, and will ascend to the top of the tube; the wire being rapidly oxydated. In this experiment, water is decomposed: its oxygen unites with the iron, while its hydrogen appears in the state of gas.

If this experiment be made with the substitution, for iron, of some metal that is not oxydated by water, as gold, for example, we obtain a mixture of hydrogen and oxygen gasses, as in the experiment of Messrs Diemen and Van Troostwyk.

In Mr Nicholson's Journal, a variety of interesting observations on the phenomena, produced by Volta's Galvanic Pile, have been published by Messrs Nicholson, Carlisle, Cruickshank, Davy, and others.

ART. IX. — *Properties and Effects of Water* *.

1. *Water contains air.* This may be shown by placing a glass vessel of water under the receiver of an air pump. During the exhaustion of the receiver, bubbles of air will be seen to ascend very plentifully. Much air escapes also from water, during ebullition, and may be collected by a proper apparatus.

2. *Water is contained in the air of the atmosphere, even during the driest weather.* Expose to the air, in a shallow vessel, a little carbonate of pot-ash (not crystallized, but the common salt of tartar.) In a few days, it will become moist, or *deliquiated.* On the same

---

* Whenever, in the course of this work, water is mentioned as an agent in any chemical operation, pure distilled water is to be understood.

principle, water exposed to the air, in a shallow vessel, disappears, being dissolved by the atmosphere.

3. *Water dissolves a great variety of solid bodies.* The substances on which it exerts this effect, are said to be soluble in water; and there are various degrees of solubility, see Art. I. No. 6.

4. *During the solution of bodies in water, a change of temperature ensues.* In most instances, an absorption of caloric, (in other words, a production of cold,) is attendant on solution, as in the examples given in Art. II. No. 9. But, in other cases, caloric is evolved, or heat is produced. Thus common salt of tartar, during solution in water, raises the temperature of its solvent; and caustic potash, in a state of dryness, does the same still more remarkably. Both carbonated and pure potash, however, when crystallized, observe the usual law, and absorb caloric during solution. Now as their difference, in the crystallized and uncrystallized state, depends chiefly on their containing, in the former but not in the latter, water chemically combined, we may infer, that the cold, produced during the solution of salts, is occasioned by the conversion of the water, which exists in these bodies, from a solid to a liquid form.

5. *During the solution of salts in water, a quantity of air is disengaged.* This air was partly contained mechanically in the salt, and partly in the water. That it does not arise entirely from the former source, is proved by varying the experiment, in the following manner. Let an ounce or two of sulphate of soda be put into a vial, and pour on this as much water as will completely fill the bottle. The air contained in

the pores of the salt will be thus disengaged; but only a small portion of the salt will be dissolved, agreeably to the principle laid down. Art. I. No. 7. Let the vial be shaken, and the whole of the salt will disappear; a fresh portion of air being liberated during solution. The air that now appears, is extricated from the water, in consequence of the affinity between the water and the salt being stronger than that between the water and the air. It is, therefore, a case of single elective affinity.

6. *During the solution of bodies, the bulk of water changes.* Take a glass globe, furnished with a long narrow neck (commonly termed a matrass) and put into it an ounce or two of sulphate of soda. Then add as much water as will fill the globe, and about three-fourths of the neck. This should be done with as little agitation as possible, in order that the salt may not dissolve, till required. Mark, by tying a little thread, the line where the water stands; and then agitate the matrass. The salt will dissolve; air will be set at liberty; and, during the solution, the water will sink considerably below its level. This contraction of bulk is owing to the diminution of temperature; and, when the water has regained its former temperature, it will also be found, that its bulk is increased by the addition of salt. The Bishop of Llandaff found that water exhibits a manifest augmentation of bulk, by dissolving only the two thousandth part of its weight of salt; a fact sufficiently decisive against that theory, which supposes pores in water capable of receiving saline bodies without an augmentation of volume.

7. *Water has its solvent power increased by diminishing the pressure of the atmosphere.* Into a Florence flask, put a pound of sulphate of soda; pour on it barely a pint of water, and apply heat so as to boil the water. The whole of the salt will be dissolved. Boil the solution for several minutes, pretty strongly, so as to drive out the air; and cork the bottle tightly, immediately on its removal from the fire. To prevent more completely the admission of air, tie the cork over with bladder. As the vessel cools an imperfect vacuum will be formed over the solution; for the steam, which arises during the ebullition, expels the air, and takes its place. The steam is condensed again, when the vessel cools. The solution, when perfectly cold, may be shaken without any effect ensuing, so long as the vessel is kept closely stopped; but, on removing the cork and shaking the vessel, the solution will immediately congeal, and heat will be produced. This experiment, besides the principle, which it is peculiarly intended to illustrate, exemplifies also the general rule laid down, Art. II. No. 10, viz. that caloric is always evolved, during the transition of bodies from a fluid to a solid state; and it furnishes a fact exactly the converse of that in which cold is produced, or caloric absorbed, during the solution of salts.

8. It is unnecessary to add any thing, to what has been already said in a former section, respecting the combination of caloric with water, constituting steam; or to the history of the phenomena attending its conversion into ice; except that, during the latter change, its bulk is enlarged in the proportion of 9 to 8, and

that, in consequence of this expansion, water, during congelation, is capable of bursting the strongest iron vessels; and becomes also specifically lighter. Hence ice swims always on the surface of water.

Art. X. — *Alcalis.*

General qualities.

The properties, common to all the three alcalis, may be shown by those of a solution of pure potash.

A. The alcalis change vegetable blue colours, as that of an infusion of violets, to green.

B. They have an acrid and peculiar taste.

C. They serve as the intermedia between oils and water, see Art I. No. 9.

D. They corrode woollen cloth; and, if the solution be sufficiently strong, reduce it to the form of a jelly.

Pure Potash, and pure Soda.

To prepare pure potash, dissolve any quantity of American or Dantzic pearlash in twice its weight of boiling water, and add it, while hot, to an equal weight of fresh quicklime, slaked to a paste with water. Boil the mixture in an iron kettle, adding as much water as is necessary to reduce it to a proper consistence, (about that of cream,) and continue stirring during an hour. Then separate the liquid alcali, either by filtering or subsidence, and boil it to dryness in a silver dish. Pour on the dry mass as much pure alcohol as is required to dissolve it; put the solution into a bottle, and let the insoluble part settle to the bottom. Then decant the alcoholic solution of potash, which swims at the top, and distil off the alcohol in an alembic * of pure silver, furnished with a glass head. Pour the alcali, when in fusion, upon a silver dish, and, when cold, break it into pieces, and preserve it in a well-stopped bottle. If the distillation of the alcohol be not carried so far, the alkali will shoot, on cooling, into regular crystals.

In the same mode may pure soda be prepared.

These alcalis have the following properties :

A. They powerfully attract moisture from the atmosphere, or deliquiate.

B. They readily dissolve in water, and produce heat during their solution, if the fused alcalis be employed ; but the crystallized alcalis generate cold, when dissolved.

C. They are not volatilized by a moderate heat, and hence have been called fixed alcalis.

Pure Ammonia.

1. Ammonia, in its purest form, subsists in the state of a gas. In order to procure it, one of the following processes may be employed.

A. Mix together equal parts of muriate of ammonia and quicklime, each separately powdered ; and introduce them into a small gas bottle or retort. Apply the heat of a lamp ; and receive the gas, that is liberated, over mercury.

B. To a saturated solution of ammonia in water, or the pure liquid ammonia, in a gas bottle, apply the heat of a lamp ; and collect the gas, as in A.

---

* The figure of an alembic may be ſeen in the plate to Nicholſon's Principles of Chemistry.

2. This gas has the following properties:

A. It has a strong and very pungent smell.

B. It immediately extinguishes flame; and is fatal to animals.

C. It is lighter than atmospheric air. Hence a jar filled with this gas, and placed with its mouth upwards, is soon found to change its contents for common air, which, being heavier, descends, and displaces the ammoniacal gas.

D. It is not inflammable; nor does it explode when mixed with hydrogen gas.

E. It is rapidly absorbed by water. A drop or two of water being admitted to a jar of this gas, confined over mercury, the gas will be immediately absorbed, and the mercury will rise, so as to fill the whole of the jar, provided the gas be sufficiently pure. Ice produces the same effect, in a still more remarkable manner.

F. Water, by saturation with this gas, acquires its peculiar smell; and constitutes what has been called liquid ammonia; or, more properly, solution of pure ammonia in water. This solution again yields its gas on applying heat, (see No. 1. B.)

G. This gas is decomposed by electricity.—Provide a jar furnished with two conductors (as described, Art. VII. No. 3, E.) and, having admitted about a cubic inch of ammoniacal gas, pass through it a succession of electrical discharges. When 150 or 200 shocks have been passed, the gas will have increased to three times its original bulk. Admit a small quantity of water; the gas will not, as before, be completely absorbed by the water, but a part will remain. Hence it appears that some new gas has been generated; and, on examination, it is found to be a mixture of hydrogen and azotic gasses.

H. The decomposition of ammonia may also be easily shown, by galvanizing, with the apparatus described page 37, a saturated solution of ammonia in water. In this experiment a considerable quantity of gas is produced. Expose this over a solution of sulphuret of potash. A small part of it will disappear, being oxygenous gas. The remainder consists of hydrogenous and azotic gasses.

ACIDIFIABLE BODIES—ACIDS—COMBINATIONS OF ACIDS WITH ALCALIS.

Art. XI. — *Acids in general.*

Acids in general have the following properties:

A. *They redden vegetable blue colours.* Hence blue vegetable infusions, and the papers stained with them, are tests of the presence of acids. To a little of the infusion of litmus, add a drop of dilute sulphuric, or any other acid. The colour will immediately change to red.

B. They have a peculiar taste, expressed by the term acid, or sour.

C. *They combine chemically with alcalis, and totally destroy the peculiar properties of those bodies.* Let a few ounce measures of water be tinged blue with genuine sirup of violets. Add some solution of pure potash, and the colour will become green. Then gradually drop in sulphuric acid, much diluted; and, if this be done very cautiously, the blue colour will be restored.

In this state, neither the alcali nor acid is in excess; or, in other words, they are exactly *saturated* with each other. One of the most remarkable properties of the alcali and the acid, when separate, disappears, therefore, on combination. And, on further examination, it will be found that all the other characteristics of the components are lost in the compound.

ART. XII. — *Carbon—Carbonic Acid—Carbonates—other Binary Compounds of Carbon.*

1. Carbon is obtained, though not absolutely pure, yet sufficiently so for the purposes of exhibition, by charring, in a covered crucible, pieces of oak, willow, hazle, or other woods, from which the bark has been previously peeled. For purposes, to which it is applied in a powdered state, it may be purified by powdering it, and washing it first with dilute muriatic acid, to separate any earths it may contain, and afterward with repeated affusions of distilled water.

2. In its aggregated state, carbon is black; perfectly insipid, and free from smell; brittle, and easily pulverized.

3. Charcoal has a singular property of absorbing gasses, without alteration. Fill a jar with common air, or any other gas, and place it over dry mercury. Take a piece of charcoal, red-hot from the fire, and plunge it in the mercury of the bath. When cold, let it be passed into the vessel of gas, without bringing it into contact with the atmosphere. A considerable diminution of the gas will be speedily effected.

From the experiments of Rouppe (Ann. de Ch. xxxii. 1) it appears, that if charcoal, which has imbibed oxygen gas, be brought into contact with hydrogen gas, water is generated.

4. Charcoal, strictly speaking, is an oxide of carbon; the diamond only being pure carbon.

Combination of Carbon with Oxygen.

3. If a piece of charcoal be introduced cold into oxygenous gas, no effect will ensue; but if the charcoal be previously made red-hot, it burns in this gas with considerable brilliancy. To perform this experiment with accuracy, and with the proper attention to the products, it should be made over mercury. The oxygen will unite with the carbon; and the product is a compound of carbon and oxygen, which subsists over mercury in the state of gas. On this account, no diminution ensues.

4. Another mode of effecting the combination of carbon with oxygen, is by driving the vapour of water over red-hot charcoal, in an apparatus similar to that described page 34, B. The water is decomposed; its oxygen combines with the carbon; while its hydrogen combines with another portion of carbon, and forms a compound, which will be hereafter described.

The union of carbon with oxygen, however produced, furnishes a compound, called

Carbonic Acid.

1. To procure carbonic acid, sufficiently pure for the exhibition of its properties, neither of the above processes is advisable. The student may, therefore, have recourse to another, the rationale of which he will not, at present, understand; but which will be

explained afterwards. Into a common gas-bottle, put a little powdered marble or chalk, and pour on this sulphuric acid, diluted with 5 or 6 times its weight of water. A gas will be produced, which those, who have an opportunity, may receive over mercury; but a mercurial apparatus is not absolutely essential, since the gas may be collected over water, if used immediately when procured. Its properties are the following:

A. *It extinguishes flame.* Set a vessel, filled with the gas, with its mouth upwards, and let down a lighted candle. The candle will instantly be extinguished.

B. *It is fatal to animals.* Put a mouse or other small animal into a vessel of the gas, and cover the vessel to prevent the contact of common air. The animal will die in the course of a minute or two.

C. *This gas is heavier than common air.* Let a long glass tube, proceeding from a gas-bottle containing the materials (No. 1.), be twice bent at right angles, like those figured in Lavoisier's 4th plate, fig. 1, E. Let the open end of the longer leg reach the bottom of a glass jar, perfectly dry within, and standing with its mouth uppermost. The carbonic acid will expel the common air from the jar because it is heavier. This superior gravity may be farther shown as follows: When the jar is perfectly filled with the gas, (which may be known by a lighted candle being instantly extinguished when let down into it,) take another jar, of rather smaller size, and place at the bottom of it a lighted taper supported by a stand. Then pour the contents of the first-mentioned jar into the second, as if you were pouring in water. The candle will be instantly extinguished as effectually as if it had been immersed in water.

It is owing to its superior gravity that carbonic acid gas is often found at the bottom of deep wells and of mines, the upper part of which is entirely free from it. Hence the precaution, used by the sinkers of wells, of letting down a lighted candle before they venture to descend in person.

D. *Carbonic acid gas is absorbed by Water.* Fill partly a jar with this gas, and let it stand a few hours over water. An absorption will gradually go on, till at last none will remain. This absorption is infinitely quicker when agitation is used. Repeat the above experiment, with this difference, that the jar must be shaken strongly. A very rapid diminution will now take place. In this manner water may be charged with nearly its own bulk of carbonic acid gas; and it acquires, when thus saturated, a very brisk and pleasant taste. This impregnation is most commodiously effected in an apparatus, sold in the glass-shops, under the name of Nooth's machine.

E. From water thus impregnated, carbonic acid is again set at liberty, on boiling the water, or on exposing it under the receiver of an air pump. During exhaustion, the gas will escape so rapidly, as to present the appearance of ebullition; and will be much more remarkable than the discharge of air from a jar full of common spring water, confined, at the same time, under the receiver, as a standard of comparison.

F. *Carbonic acid gas, when combined with water, reddens vegetable blue colours.* This may be shown by dipping into water thus saturated a bit of litmus paper, or by mixing with a portion of it about an equal bulk of the infusion of litmus. This fact establishes the title of the gas to be ranked among acids.

G. *Carbonic acid gas precipitates lime water.* This character of the gas is necessary to be known, because it affords a ready test of the presence of carbonic acid whenever it is suspected. Pass the gas, as it proceeds from the materials, through a portion of lime water. This, though perfectly transparent before, will instantly grow milky. Or mix equal measures of water saturated with carbonic acid and lime water. The same precipitation will ensue.

11. *By the application of the test G, it will be found, that carbonic acid is generated in several cases of combustion.* Fill the pneumato-chemical trough with lime water, and burn a candle, in a jar filled with atmospheric air, over the lime water till the flame is extinguished. On agitating the jar, the lime water will become milky. — The same appearances will take place, more speedily and remarkably, if oxygenous gas be substituted. The carbonic acid, thus formed during combustion, by its admixture with the residuary air, renders it unfit for supporting flame sooner than it otherwise would be. Hence, if a candle be burnt in oxygenous gas, it is extinguished long before the oxygen is totally absorbed, because the admixture of carbonic acid with oxygen gas, in considerable proportion, unfits it for supporting combustion. When-

ever any substance, by combustion in oxygenous gas or common air over lime water, gives a precipitate, soluble with effervescence in muriatic acid, we may confidently infer that it contains carbon.

12. *The respiration of animals is another source of carbonic acid.* On confining an animal, in a given portion of atmospheric air, over lime water, this production of carbonic acid is evinced by a precipitation. The same effect is, also, produced more remarkably in oxygenous gas. The production of carbonic acid, by respiration, may be proved, also, by blowing the air from the lungs, with the aid of a quill, through lime water, which will immediately grow milky. The carbonic acid, thus added to the air, unfits it for supporting life, not merely by diminishing the proportion of oxygen gas, but apparently by exerting a positively noxious effect. Hence a given quantity of air will support an animal much longer, when the carbonic acid is removed as fast as formed, than when suffered to remain in a state of mixture. It has been found that an atmosphere, consisting of oxygen gas and carbonic acid, is fatal to animals, though it contain a larger proportion of oxygen than the air we commonly breathe.

13. *Carbonic acid gas exerts powerful effects on living vegetables.* These effects, however, vary according to the mode of its application.

Water, saturated with this gas, proves highly nutritive, when applied to the roots of plants. The carbonic acid is decomposed, its carbon forming a component part of the vegetable, and its oxygen being liberated in a gaseous form.

On the contrary, carbonic acid applied as an atmosphere, by confining a living vegetable in this gas over mercury, is injurious to the health of the plant, especially in the shade. M. Saussure, jun. found that a proportion of carbonic acid in common air, greater than one eighth, is always injurious to vegetation; but that in this proportion it promotes their growth, and is manifestly decomposed.

Carbonates in general.

Carbonic acid is susceptible of combination with alkalis, earths, and metals, and forms an order of compounds termed carbonates. At present, however, we shall only attend to the results of its union with alkalis.

Carbonate of Potash.

A. *Carbonic acid gas is very abundantly absorbed by a solution of pure potash.* The simplest mode of showing this is the following. Fill a common phial with this gas over water; and, when full, stop it by applying the thumb. Then invert the bottle in a solution of pure potash, contained in a cup, and rather more in quantity than is sufficient to fill the bottle. The solution will rise into the bottle, and, if the gas be pure, will fill it entirely. Pour out the alcaline liquor, fill the bottle with water, and again displace it by the gas. Proceed as before, and repeat the process several times. It will be found that the solution will condense many times its bulk of the gas; whereas water combines only with its own volume.

B. *The changes effected in the alcali may next be examined.* It will be found to have lost much of its corrosive and penetrating taste, and will no longer destroy the texture of woollen cloth; but it still turns green the blue infusion of vegetables. Before its absorption of this gas, no remarkable change ensued on mixing it with diluted sulphuric acid; but, if this or any other acid be now added, a violent effervescence will ensue, arising from the escape of the gas that had been previously absorbed. If the mixture be made in a gas-bottle, the gas, that is evolved, may be collected, and will be found to exhibit every character of carbonic acid.

C. In this state of combination with carbonic acid, potash generally occurs in the arts. The potash and pearlash of commerce, and the salt of tartar and salt of wormwood of the shops, are carbonates of potash of different degrees of purity. The quantity of carbonic acid, contained in these alcalis, may be learned by a very simple experiment. Put one or two hundred grains of the alcali into a Florence flask, and add a few ounce measures of water. Take, also, a phial filled with dilute sulphuric acid, and place this, as well as the flask, in one scale. Balance the two, by putting weights into the opposite scale; and, when the equilibrium is attained, pour gradually the acid into the flask of alcali, till an effervescence no longer ensues. When this has ceased, the scale containing the weights will be found to preponderate. This shows that the alcali, by combination with an acid, loses considerably of its weight; and the exact amount of the loss may be ascertained by adding weights to the scale containing the flask and phial, till the balance is restored.

D. As it is sometimes of importance to know what proportion of real alcali a given weight of potash or pearlash contains, it may be proper to point out how this information may be acquired. The strength of the alcali is in proportion to the quantity of an acid required to saturate it. Thus, if an ounce of one kind of potash requires, for saturation, a given quantity of sulphuric acid, and an ounce of another kind requires twice that quantity, the latter is twice as strong as the former. In order, however, to obtain a sufficiently accurate standard of comparison, it will be necessary to employ, constantly, an acid of the same strength. This may be effected, though not with absolute uniformity, yet sufficient for ordinary purposes, by diluting the common oil of vitriol of commerce to the same degree. For example, let the standard-acid consist of one part of sulphuric acid and five of water. The strength of an alcali will be learned, by observing what quantity of this acid a given quantity of alcali requires for saturation. For this purpose, put half an ounce of the alcali, or any other definite weight, into a jar with a few ounces of water, and filtre the solution; weigh the dilute acid employed, before adding it to the alcali; then pour it in gradually, till the effervescence ceases, and till the colour of litmus paper, which has been reddened with vinegar, ceases to be restored to blue. When this happens, the point of saturation will be attained. Weigh the bottle to ascertain how much acid has been added, and the loss of weight will indicate the strength of the alcali. Another less accurate mode of determining the strength is founded on the following property of carbonate of potash.

E. *Carbonate of potash dissolves very readily in water, which, at the ordinary temperature, takes up more than its own weight.* Hence, when an alcali, which should consist almost entirely of carbonate of potash, is adulterated, as very often happens, with substances of little solubility, the fraud may be detected by trying how much of one ounce will dissolve in two or three ounce measures of water. In this way I have detected an adulteration of one third. There are certain substances of ready solubility, however, which may be used in adulterating ashes, as common salt for example; and, when this is done, we must have recourse to the above-mentioned test for the means of discovery.

F. Carbonate of potash, in the states which have been already described, is far from being completely saturated with acid. This sufficiently appears from its strongly-alcaline taste. . It may be much more highly charged with carbonic acid, by exposing its solution to streams of carbonic acid gas, in a Nooth's machine, or other apparatus. When a solution of alcali, after this treatment, is slowly evaporated, it forms regular crystals. In this state the alcali constitutes the crystallized carbonate of potash, which contains, per cent. 40 parts of alcali, 43 of acid, and 17 of water. It has therefore a much larger proportion of water and of acid than the common carbonate, 100 parts of which are composed of 70 parts of alcali, 23 of acid, and 5 of water.

G. The crystallized carbonate differs from the common one in the regularity of its form; in the greater mildness of its taste; in remaining dry when exposed to a moist atmosphere; and in being more sparingly soluble in water, which at the ordinary temperature takes up only one fourth of its weight. When carefully prepared, this is the purest form in which carbonate of potash can be obtained.

H. Carbonate of potash, in all its forms, is decomposed by the stronger acids; as the sulphuric, nitric, and muriatic, which unite with the alcali, and set the gas at liberty.

Carbonate of Soda.

A. The absorption of carbonic acid gas, by a solution of pure soda, may be exhibited by experiments similar to those directed to be made on the solution of potash. Indeed, every thing that has been said of the preceding carbonate will apply to this; except that the carbonate of soda has a less strong affinity for water. Hence it continues dry, when exposed to the atmosphere, and even gives up a part of its water of crystallization, the crystals losing their transparency and something of their weight. Hence, also, it requires a greater quantity of water for solution, than common carbonate of potash, water taking up only half its weight. The crystals, too, differ considerably in form and size from those of the former carbonate.

The carbonate of soda is known in commerce by the names of barilla, fossil, or mineral, alcali, &c.; but as applied to the uses of the arts it is never met with pure.

Carbonate of Ammonia.

A. Ammonia, in its pure state, exists in the form of a gas, permanent over mercury only; and carbonic acid has, also, the form of an aërial fluid. But, when these two gasses are mixed together over mercury in proper proportions, (viz. one measure of carbonic acid to two or three of alcaline gas,) they both quit the state of gas, and are entirely condensed into a white solid body, termed carbonate of ammonia.

B. Carbonate of ammbnia retains, in a considerable degree, the pungent smell of the pure volatile alcali. It is, also, unlike the other carbonates, volatilized by a very moderate heat, and evaporates without entering previously into a liquid state. The vapour that arises may be again condensed in a solid state; affording an example of *sublimation*. This may be shown, by applying heat to the carbonate of ammonia in a retort, to which a receiver is adapted. The carbonate will rise and be condensed in the receiver in the form of a white crust.

C. This carbonate does not attract moisture from the air, but, on the contrary, loses weight. Its other properties resemble those of the carbonates of potash and soda. The mode of preparing it will be described hereafter.

Gaseous Oxyd of Carbon.

This combination of carbon with oxygen has a less proportion of the latter than is found in carbonic acid. Its discovery was announced in Nicholson's Journal, for April 1801, by Mr. Cruickshank, and in the 38th vol. of the Annales de Chimie, through Cit. Guyton, by Clement and Desormes, whose experiments are continued in the 39th vol. p. 26. The Dutch chemists, however, in vol. 43, object to its being considered as a distinct gas, and regard it merely as a carburet of hydrogen. But their objections do not appear sufficiently strong to prevent the acknowledgment of the gaseous oxyd as a new and peculiar species.

It may be procured by any of the following processes:

1. By the distillation of the white oxyd of zinc, with $\frac{1}{8}$ its weight of charcoal, in an earthern or glass retort; from the scales which fly from iron in forging mixed with charcoal; from the oxyds of lead, manganese, or, indeed, of almost every imperfect metal when heated in contact with powdered charcoal. It may also be obtained from the substance which remains after preparing acetic acid from acetite of copper.

2. From carbonate of barytes or of lime (common chalk), distilled with about $\frac{1}{3}$ of charcoal; or with rather a larger proportion of dry iron filings, which afford it quite free from hydrogen.

The last product of the distillation is the purest, but still contains carbonic acid, which must be separated by washing the gas with lime water.

Its properties are as follow:

A. It has an offensive smell.

B. It is lighter than common air, in the proportion of 956 to 1000. One hundred cubical inches weigh 30 grains.

C. It is inflammable, and, when set fire to, as it issues from the orifice of a small pipe, burns with a blue flame. When mixed with common air, it does not explode like other inflammable gasses, but burns silently with a lambent blue flame. It detonates, however, with oxygen gas.

D. When a stream of this gas is burnt, in the manner described in speaking of hydrogen gas, page 32, no water is condensed on the inner surface of the glass globe, a proof that the gaseous oxyd contains no hydrogen.

E. One hundred measures require between 40 and 44 of oxygen gas for saturation, when detonated together, and 76 measures of carbonic acid are generated. It contains per cent. 70 oxygen and 30 carbon, according to Cruikshank; but, in composition, it varies according to the mode of its preparation.

Combination of Carbon with Hydrogen, forming Carbonated Hydrogenous Gas.

1. When water is decomposed, by passing its vapour over red hot charcoal[*], we obtain two different products. Carbonic acid is formed, in consequence of the union of the carbon with the oxygen of the water: and the hydrogen of the water, combining

---

[*] See Lavoisier's Elements, Chap. viii.

with another portion of carbon, constitutes the carbonated hydrogenous gas. The carbonic acid may be separated by agitating the produced gas in contact with lime and water, mixed together so as to be of the consistence of cream, and the carbonated hydrogen gas will remain pure.

2. This gas has the following qualities:

A. *It is sparingly absorbed by water.*

B. *It is inflammable.* This may be shown by burning it in the manner directed in Art. VII. No. 3, B. The colour of the flame, however, may be observed to differ from that of hydrogen gas, inclining rather to a deep blue.

C. *When fired over mercury, carbonic acid gas, and water, are the products.* In burning pure hydrogen gas, water only is generated; but, in the combustion of this gas, two inflammable bodies are present, viz. hydrogen and carbon. The production of carbonic acid may, also, be shown by burning the gas over lime water, by means of a bladder and bent pipe, as directed, page 32, A. The lime water will soon become milky.

D. *This gas is heavier than pure hydrogen gas.* Soap bubbles, blown with it, descend like the common ones; and a jar filled with it, and held inverted a few minutes, exchanges its contents for common air *.

E. In composition and properties it varies greatly, according to the substances from which it has been procured. That, obtained from moistened charcoal, con-

---

* For some excellent observations on the combinations of carbon with hydrogen, consult Mr Cruickshank's papers, in the 5th vol. of Nicholson's 4to Journal.

tains, per cent. about 75 carbon and 25 oxygen by weight; its s. g. is to that of common air as 453 to 1000; and 100 measures require 66 of oxygen for saturation, which give 40 of carbonic acid.

ART. XIII. — *Sulphur — Sulphuric Acid — Sulphates — Binary Compounds of Sulphur.*

Sulphur.

1. *Sulphur occurs in two different forms;* that of flowers and of stick sulphur. The former is generally purest.

2. *Sulphur is readily fused.* A very gentle heat is sufficient to melt it; and, if very slowly cooled, it forms regular crystals.

3. *Sulphur is volatilized by heat.* A little sulphur may be put into the bottom of a tube, the mouth of which is loosely stopped with paper, to prevent the free access of air. On applying heat, the sulphur will rise to the top of the tube.

4. *Sulphur does not dissolve in water.*

5. *It is inflammable.* In the open air it burns with a blue flame, and emits a very penetrating smell. When burnt in a confined portion of common air, an absorption takes place, but the sulphur is extinguished before the whole of the oxygen is consumed. In oxygenous gas, it burns with a very beautiful and brilliant light, and the absorption is more remarkable, but is still far from being complete. The product of both these combustions, is

Sulphuric Acid *.

1. Though this is not the mode in which sulphuric acid is ordinarily prepared, yet it will be proper for the chemical student to examine the result of this combustion, on account of the simplicity of the process. Let the glass bell, under which sulphur has been burnt, be rinced out with a little water. This water will have an acid taste, will turn vegetable blue colours red, and will effervesce with carbonated alcalis. It is, therefore, an acid; and, as it is composed of sulphur and oxygen, it is termed the sulphuric acid. The properties of this acid must be exhibited by a portion of that usually found in the shops, or contained in the chest. They are as follows:

A. *Sulphuric acid has a thick and oily consistence;* as may be seen by pouring it from one vessel into another.

B. *It is nearly twice as heavy as water.* This will appear from weighing a small phial filled with the acid, and afterward filled with distilled water.

C. *In a pure state it is perfectly limpid and colourless.*

D. *When mixed suddenly with water, considerable heat is produced.* A diminution of bulk also ensues; that is, one measure of acid and one of water do not occupy the space of two measures, but considerably less. Owing to the heat produced by its admixture with water, the dilution should be conducted very gradually; and the acid should be added to the water

---

* Much sulphureous acid is also generated in these processes.

by small portions at once, allowing each portion to cool before a fresh addition is made. On the principle of its attraction for water is to be explained, also, the rapid increase of weight which the acid acquires when exposed to air.

E. *A perfectly pure sulphuric acid remains quite limpid during dilution.* The sulphuric acid, however, commonly found in the shops, under the name of oil of vitriol, on admixture with water, deposits a white powder, in considerable quantity, consisting of various impurities.

F. *To purify sulphuric acid,* it must be distilled in a glass retort, placed in the sand-bed of a reverberatory furnace. This process is a very difficult one; and an inexperienced chemist should, therefore, not attempt it. It may be less perfectly purified by diluting it with an equal weight of water, allowing the impurities to settle, decanting the clear liquor, and evaporating it, to the proper degree, in a glass vessel.

G. *Sulphuric acid is decomposed at the temperature of the atmosphere, by inflammable substances, and acquires a dark colour.* The addition of a little brown sugar, or a drop of oil, to a portion of the acid, imparts to it a brownish hue, which in time changes to black. Hence this acid should always be kept in bottles with glass stoppers; for, a small bit of cork, if dropped into a considerable quantity, changes it in the manner that has been pointed out.

H. *In high temperatures, sulphuric acid is still farther decomposed by combustible bodies.* Into a glass retort put such a quantity of sulphuric acid as will fill about one fourth part of it, and add a small portion of powdered charcoal. On applying the heat of a lamp, gas will be produced very abundantly. Let this gas be conveyed, by a tube fixed to the mouth of a retort, and bent in the proper manner, into an inverted jar of water; or, if it can be had, into an inverted jar of quicksilver in a mercurial apparatus. During this operation, the carbon attracts part of the oxygen of the sulphuric acid, and forms carbonic acid gas. But the sulphur is not entirely disoxygenated, and a compound is, therefore, formed of sulphur and oxygen, containing less oxygen than the sulphuric acid. This compound exists in the state of a gas, and its properties may next be examined. To avoid, however, the complication which the admixture of carbonic acid with this new product introduces into the experiments, it may be proper to prepare it in a mode less objectionable, but the rationale of which cannot at present be explained. This consists in dissolving one part, by weight, of quicksilver in two of sulphuric acid, and boiling the mass to dryness. The dried mass, still remaining in the retort, is next to be distilled in a strong sand-heat, a glass globe being interposed between the retort and the receiving trough, to condense any sulphuric acid that may escape decomposition. (See Lavoisier's 4th plate, fig. 1, G.) The gas, thus obtained, is termed, conformably to the principles of the new nomenclature,

Sulphureous Acid Gas.

Its properties are the following:

A. *It has a pungent and suffocating smell,* exactly resembling that which arises from burning sulphur.

B. *It is heavier than atmospherical air.*

C. *It extinguishes burning bodies, and kills animals.*

D. *It has the property of whitening or bleaching silk.*

E. *It is absorbed by water,* but only in small proportion.

F. *This watery solution does not redden infusion of litmus,* as acids in general do, but totally destroys its colour.

G. *Sulphuric acid, saturated with this gas,* (which may be effected by passing the gas through the acid,) *acquires the property of assuming a solid form,* by a moderate reduction of its temperature.

H. *Sulphureous acid is again converted to the state of sulphuric by restoring oxygen to it.* To a portion of water saturated with this gas, add a little oxyd of manganese, a substance that contains much oxygen loosely combined. The pungent smell of the water, and the other characteristics of sulphureous acid, will soon disappear.

I. If sulphureous acid gas and fresh muriate of tin are brought into contact over mercury, the volume of the gas is speedily diminished, sulphur is deposited, and the simple muriate becomes an oxygenized muriate of tin. (Accum.)

Both these acids are susceptible of combination with alcalis.

Combination of Sulphuric Acid with Alcalis.

Sulphate of Potash.

This salt may be formed by saturating the carbonate of potash with sulphuric acid, and crystallizing the solution. Its properties are the following:

A. *It crystallizes* in small six-sided prisms, terminated by six-sided pyramids with triangular faces.

B. *It has a bitter taste.*

C. *It decrepitates,* or crackles, when thrown on a red hot iron or on red hot coals, and is volatilized in a strong heat.

D. *Water, at 60° of Fahrenheit, takes up only one sixteenth of its weight:* but boiling water dissolves one fifth.

E. 100 parts contain 30.21 acid, 64.61 alcali, and 5.18 water.

G. *This sulphate is decomposed, in high temperatures, by carbon.* Mix any quantity of the salt with one fourth of its weight of charcoal finely powdered, and expose the mixture, in a crucible, to a strong heat. The carbon will unite with the oxygen of the sulphuric acid, and will escape in the state of a gas. What remains is a compound, hereafter to be described, of sulphur and potash.

Sulphate of Soda.

A. This salt forms regular octahedral crystals, of a prismatic or cuneiform figure, the two terminating pyramids of which are truncated near their basis.

B. It has a more bitter taste than the preceding, and melts more easily in the mouth.

C. It swells upon a heated iron, in consequence of the loss of its water of crystallization, and a white powder is left.

D. By exposure to the atmosphere, it effloresces and loses weight.

E. It is very soluble in water, 3 parts of which, at 60° of temperature, dissolve one of the salt; and boiling water dissolves its own weight.

F. It contains per cent. 14 acid, 22 alkali, and 64 water.

G. It is decomposed by charcoal like the preceding salt, and a compound remains of sulphur and soda.

Sulphate of Ammonia.

A. The sulphate of ammonia forms long flattened prisms with six sides, terminated by six-sided pyramids.

B. It slightly attracts moisture from the air.

C. It liquifies by a gentle heat, and is volatilized. If a stronger heat be applied, it is decomposed. See Mr Hatchett's paper, in Phil. Trans. 1796, or Davy's Researches.

D. The pure fixed alkalis, potash and soda, seize the sulphuric acid, and set at liberty the alcali. Hence a strong smell of ammonia arises on the admixture of pure soda or potash with this salt.

The combinations of sulphureous acid with alcalis have no peculiar qualities that are likely to prove interesting to the general student. Those, however, who may wish to pursue this subject, I refer to some interesting papers in the Annales de Chimie, vol. 2 and 24.

Binary Compounds of Sulphur. — 1st *With Alcalis.* — 2d *With Hydrogen.*

The combinations of sulphur with the two fixed alcalis, soda and potash, are so similar in properties, that what is said of the one will equally apply to the other.

1. Sulphur may be united with these alcalis either in the dry or humid way. To prepare a sulphuret in the dry way, mix equal parts of sulphur and of carbonate of potash or soda, in a perfectly dry state, and fuse the mixture in a crucible. The melted mass, when poured out, will have a reddish, or liver colour. Or, a sulphuret may be formed by the decomposition of sulphates by charcoal, see preceding G. The process, in the moist way, consists in boiling together flowers of sulphur and a solution of pure potash or soda in a glass vessel. The sulphur is thus dissolved.

2. Sulphurets of alcalis have the following qualities.

A. *In a moist state they emit an offensive smell, and have a disagreeable taste.*

B. *They change to green the colour of violets,* in the same manner as uncombined alcalis.

C. *They blacken the skin,* silk, and other animal substances.

D. *They are decomposed by all acids.* Into a Nooth's machine put a weak solution of sulphuret of alcali, and pass through it streams of carbonic acid gas. In the course of a few days, the sulphur will be precipitated, and a carbonate of alcali obtained. This decomposition ensues, instantly, on adding, to a solution of a sulphuret, any of the stronger acids, as the sulphuric, nitric, or muriatic; and we obtain a compound of the alcali with the respective acid employed.

E. *The liquid sulphurets absorb oxygenous gas.* This may be shown by the experiments already described. (Art. VI.) If the change thus effected be examined, it will be found that the oxygen has combined with the sulphur, and formed sulphuric acid, which, uniting with the alcali, has composed the sulphate of potash.

F. If dilute muriatic acid be poured on the solution of sulphuret of potash or soda, a violent effervescence will ensue, and a very offensive gas be disengaged. This gas may be collected over water. It is termed

Sulphuretted Hydrogen Gas.

1. This gas may be obtained in the foregoing manner, or from a mixture of three parts by weight of iron filings and one of sulphur, previously melted together in a covered crucible. A portion of the fused mass may be put into a gas-bottle, and diluted sulphuric or muriatic acid poured on it, which will extricate the sulphuretted hydrogen gas.

2. Its properties are the following:

A. *Its smell* is extremely offensive, resembling that of putrified eggs.

B. *It is inflammable,* and burns either silently or with an explosion, accordingly as it is previously mixed or not with oxygen gas or atmospheric air.

During this combustion, water results from the union of the hydrogen with the oxygen, and sulphuric and sulphureous acids from that of the oxygen and sulphur.

C. *It tarnishes silver*, mercury, and other polished metals, and instantly blackens white paint.

D. *It is absorbed by water*, which thus acquires the peculiar smell of the gas. It is this gas which gives to the Harrogate and some other natural waters their peculiar smell.

E. *Water saturated with this gas turns red the infusion of violets*, in this respect producing the effect of an acid.

F. *It is copiously absorbed by alcalis*, which thus acquire colour, smell, and the property of diminishing oxygen gas. The compounds of this gas with alcalis are termed hydro-sulphurets. Thus, the compound of this gas with potash is named hydro-sulphuret of potash, and differs from the sulphuret of potash in containing hydrogen besides sulphur. From these combinations the gas is liberated by acids *.

ART. XIV.—*Combination of Azote with Oxygen, constituting Nitric Acid,—Nitrous Gas,—Nitrous Oxyd,—and Compounds of Nitric Acid with Alcalis.*

1. The direct combination of azote and oxygen, affording a decisive synthetic proof of the nature of this acid, may be effected by passing the electric

---

* See Berthollet's memoir on the combinations of sulphuretted hydrogen gas, Ann. de Chim. vol. xxv. and Vauquelin on the characters and crystals of hydro-sulphuret of potash, vol. xlii.

shock through a mixture of azotic and oxygen gasses. The circumstances of this experiment, however, cannot be understood without the aid of a plate and of a very detailed description, for both of which I must refer to Mr. Cavendish's paper in the Phil. Trans. for 1785, &c.

2. The analysis of the acid may be obtained by driving it through a red-hot porcelain tube, and receiving the generated gasses, which turn out to be a mixture of azotic and oxygenous gasses.

3. The nitric acid has the following properties :

A. *It is heavier than water,* in the proportion of 1.5 to 1.

B. *It is perfectly limpid and colourless.*

C. *It gives a yellow stain to the skin.*

D. *It produces heat when diluted with water,* but by no means equal to that excited by diluting sulphuric acid.

E. *It becomes coloured by exposure to the sun's light,* passing first to a straw colour, and then to a deep orange. This effect is produced by the union of the light of the sun with oxygen, in consequence of which the proportion of the acidifying principle to the azote is diminished.

F. *This acid retains its oxygen with but little force.* Hence it is decomposed by all combustible bodies, which are oxydated by it, with more or less rapidity in proportion to their affinity for oxygen. Charcoal decomposes it, and carbonic acid is formed, azotic gas being produced at the same time, if the proportion and temperature, in which the experiment is made, be duly regulated. To effect the complete decomposition of nitric acid by charcoal, it may be driven over that substance made red-hot in a porcelain tube.

G. *The acid is also decomposed by metals,* as iron, tin, zinc, copper, &c. and with different phenomena, according to the affinity of each metal for oxygen. This may be seen by pouring some strong nitric acid on iron filings or powdered tin. Violent heat, attended with red fumes, will be produced, and the metals will be oxydated.

H. If the action of metals on nitric acid be more moderately conducted, a new product is obtained in a gaseous state. Dilute some nitric acid with an equal weight of water, and dissolve, in this, some turnings of copper, or a portion of quicksilver, applying heat if necessary. This must be done in a gas-bottle, and the product received over water is

Nitrous Gas.

The properties of this gas are the following:

A. *It is permanent over water.*

B. *When well washed with water it is not acid.* It will be found not to redden litmus paper, when introduced into it through water.

C. *It extinguishes flame,* and is fatal to animals.

D. *When mixed with oxygenous gas, red fumes arise;* heat is evolved; and a diminution takes place; and, if the two gasses be in proper proportion and perfectly pure, they disappear entirely. Nitrous acid, at the same time, is regenerated.

E. *The same appearances ensue, less remarkably, with atmospheric air;* and the diminution is only proportionate to the quantity of the oxygen gas which it contains. Thus 100 measures of atmospheric air and 85 of nitrous gas, containing 13 per cent. of azotic gas, are reduced, by admixture, to about 39; and deducting 11 measures for the azotic gas, contained in 85 measures of nitrous gas, we find that the air, under examination, contained 28 per cent. of oxygen gas. On this principle, of its condensing oxygenous but no other gas, is founded the application of nitrous gas to the purpose of eudiometry, or of ascertaining the purity of air. The sources of error, however, in its employment in this mode, are such as to forbid our relying implicitly on the results which it may afford, notwithstanding the improvements lately made in its application by M. Humboldt, (see Annales de Chimie, Vol. 28, p. 123.) I prefer the sulphuret of potash as a more certain test of the purity of air; and in this opinion I have the sanction of M. Berthollet, (see Ann. de Ch. Vol. 34, p. 73 *.)

F. *The generation of an acid, by the admixture of nitrous gas with common air or oxygen gas, may be shown by the following experiment.* Paste a slip of litmus paper within a glass jar, near the bottom; and into the jar, filled with and inverted in water, pass as much nitrous gas, previously well washed, as will displace the water below the level of the paper. The colour of the litmus will remain unchanged; but, on passing up atmospheric air or oxygen gas, it will be immediately reddened.

---

* Since this paragraph was written, an improvement has been made in eudiometry which will be described in the subsequent part of this section.

G. *That the peculiar acid, thus produced, is the nitrous*, will appear from the following experiment. Into a jar filled with and inverted in mercury, pass a small quantity of a solution of pure potash; and, afterward, measures of oxygen and nitrous gasses, separately, and in proper proportion. On removing the solution from the jar, exposing it for some time to the atmosphere, and afterward evaporating it, crystals of nitrate of potash will be formed, a salt which is ascertained to be formed of potash and nitrous acid.

H. *Nitrous gas is absorbed by nitric acid*, which, by this absorption, is considerably changed in its properties. Pass the gas, as it issues from the materials that afford it, through colourless nitric acid. The acid will undergo successive changes of colour, till at last it will become orange coloured and fuming. In this state it is called nitrous acid, because it contains a less proportion of oxygen than the colourless nitric.

I. *The nitrous gas, thus absorbed, is expelled again by a gentle heat.* This may be shown by gently heating the acid coloured in expt. H, till it again becomes limpid. In this experiment light should be excluded.

K. *Nitrous gas is decomposed by exposure to bodies that have a strong affinity for oxygen.* Thus iron filings decompose it, and become oxyded, affording a proof of the presence of oxygen in this gas. Sulphuret of potash, &c. have a similar effect.

L. *Nitrous gas is absorbed by the green sulphate and muriate of iron* *, which do not absorb azotic gas. To

---

* For an account of these salts, see Art. xxiv.

ascertain, therefore, how much azotic gas a given quantity of nitrous gas contains, let it be exposed in a graduated tube over one of these solutions. This information is necessary previously to deducing, from its effects on atmospheric air, the proportion of oxygen gas.

From the important use which is now made of this solution of nitrous gas, in eudiometry, it may be proper to describe the mode of its preparation.

Dissolve as much of the green sulphate of iron in water as the water will take up, or dissolve iron filings in sulphuric acid, diluted with five or six parts of water, leaving an excess of the iron in order to insure the perfect saturation of the acid. Fill a pretty wide-mouthed bottle with this solution, invert it in a cupful of the same, and into the inverted bottle receive the nitrous gas from nitric acid and quicksilver, shaking the bottle frequently. The colour of the solution will change to black, and the production of gas and agitation are to be continued till the absorption can be carried no farther. The impregnated solution should be preserved in a number of small bottles, not holding more than an ounce each.

M. *A very interesting experiment, affording a synthetic proof of the constitution of nitrous gas*, we owe to Dr Milner of Cambridge *. Into an earthen tube, about 20 inches long and ¾ inch wide, open at both ends, put as much coarsely-powdered manganese, as is sufficient nearly to fill it. Let this be placed, horizontally, in a furnace, having two openings opposite

---

* Phil. Trans. 1789.

to each other. To one end of the earthen tube adapt a retort, containing a strong solution in water of pure ammonia, and to the other a bent glass tube. Let a fire be kindled in the furnace; and, when the manganese may be supposed to be red-hot, drive over it the vapour of the ammonia. The alcali will be decomposed, its hydrogen, uniting with part of the oxygen combined with the manganese, will form water, while its azote, uniting with another portion of the oxygen, will constitute nitrous gas. The gas, thus generated, may be collected by the usual apparatus.

N. *Another fact, showing the mutual relation of ammonia and of the compounds of azote was discovered some years ago by Mr Wm Higgins*[*]. Moisten some powdered tin (which is sold under this name by the druggists) with strong nitric acid; and, when the red fumes have ceased to arise, add some quick-lime or solution of pure potash. A strong smell of ammonia will be immediately produced.

Gaseous Oxyd of Azote. — Nitrous Oxyd of Davy.

1. This compound, also consisting of oxygen and azote, but in different proportions, may be obtained by several processes.

A. By exposing common nitrous gas for a few days to iron filings, or to various other bodies strongly attracting oxygen, this gas is changed into the gaseous oxyd.

B. By dissolving zinc or tin in dilute nitric acid.— But by neither of these processes is the gas obtained

---

[*] See his Comparative View of the Phlogistic and Antiphlogistic Theories 2d edition, page 309, note.

sufficiently pure for exhibiting its qualities. To procure it in a state of purity the following process is the best.

C. To dilute nitric acid, add carbonate of ammonia till the acid is saturated. Then evaporate the solution; and, to supply the waste of alcali, add occasionally a little more of the carbonate. Let the solution be evaporated by a very gentle heat to dryness. The salt thus obtained is next to be put into a glass retort, and distilled with a sand-heat not exceeding 500° Faht. The heat of an Argand's lamp is even sufficient. The gas may be collected over water, and allowed to stand a few hours before it is used, during which time it will deposite a white cloud, and will become perfectly transparent.

The gas thus obtained was termed, by the society of Dutch chemists, gaseous oxyd of azote, but, for the sake of brevity, and as more conformable to the nomenclature of other compounds of azote, I shall use, with Mr. Davy, the name of nitrous oxyd *.

This gas has the following properties:

A. *A candle* burns in this gas with a brilliant flame and crackling noise. Before its extinction, the white inner flame becomes surrounded with an exterior blue one.

B. *Phosphorus* introduced into it in a state of inflammation burns with increased splendor.

C. *Sulphur*, introduced into it when burning with a feeble blue flame, is instantly extinguished. But

---

* For a full account of this gas, consult M. Davy's Researches, Chemical and Philosophical. London. Johnson, 1800.

when in a state of active inflammation it burns with a vivid and beautiful rose-coloured flame.

D. *Red-hot charcoal* burns in it more brilliantly than in the atmosphere.

E. *Iron wire* burns in this gas with much the same appearances as in oxygenous gas.

F. *It is rapidly absorbed by water that has been previously boiled,* about $\frac{1}{30}$ the original bulk of the gas remaining uncondensed. A quantity of gas, equal to rather more than half the bulk of the water, may be thus made to disappear.

G. *Water that has been saturated with this gas gives it out again, unchanged, when heated.*

H. *It does not change blue vegetable colours.*

I. *It has a distinctly-sweet taste* and a faint but agreeable odour.

K. *It is not diminished* by admixture with either oxygen or nitrous gas,

L. *A mixture of this gas with hydrogen gas detonates loudly.*

M. *Animals, when wholly confined in this gas, die speedily.*

N. *One of the most extraordinary properties of this gas is exhibited in its action on the human body when received into the lungs.* When thus employed, it does not prove fatal, because, when received into the lungs, it is mixed and diluted with the atmospherical air present in that organ. To administer the gas, it may be introduced into an oiled silk bag or clean bladder, furnished with a stop-cock, and may be breathed repeatedly from the bag and back again as long as it will last. The sensations that are produced vary greatly in persons of different constitution; but in general they are highly pleasurable, and resemble those attendant on the pleasant period of intoxication. Great exhilaration, an irresistible propensity to laughter, a rapid flow of vivid ideas, and an unusual fitness for muscular exertion are the ordinary feelings it produces. These pleasant sensations, it must be added, are not succeeded, like those accompanying the grosser elevation from fermented liquors, by any subsequent depression of nervous energy.

O. From the experiments of Mr. Davy, it appears that 100 parts by weight of this gas contain 36.7 oxygen, and 63.3 azote, or, excluding decimals, 37 oxygen and 63 azote.

Nitrate of Potash.

A direct synthetic proof of the composition of this salt may be obtained by saturating nitric acid with potash, either pure or in a carbonated state. The solution on evaporation yields crystals of nitrate of potash or nitre.

2. This salt has the following properties:

A. *It crystallizes* in prismatic octahedrons, generally constituting six-sided prisms, terminated by two-sided summits.

B. *For solution*, it requires seven times its weight of water at 60° of Faht.; and boiling water takes up its own weight.

C. *By the application of a gentle heat it fuses*, and being cast in moulds, forms what is called Sal Prunelle.

E. *If a red heat be applied, nitrate of potash is decomposed in consequence of the destruction of its acid.*

By distilling it in an earthen retort, or in a gun-barrel, oxygenous gas may be obtained in great abundance, one pound of nitre yielding about 12,000 cubic inches of sufficient purity for common experiments but not for nice purposes.

E. *Nitrate of potash, that has been made red-hot, seems to contain an acid less highly oxygenated than the common nitric acid,* and having a weaker affinity for alcalis. For, if acetic acid be poured on nitre that has been thus treated, the nitrous acid is expelled in red fumes, whereas common nitre is not at all affected by acetic acid.

F. *Nitrate of potash is rapidly decomposed by charcoal.* This may be shown by mixing two parts of powdered nitre with one of powdered charcoal, and setting fire to the mixture in an iron vessel under a chimney. The products of this combustion, which may be collected by a proper apparatus, are carbonic acid and azotic gasses. Part of the carbonic acid also remains attached to the residuary alcali, and may be obtained from it on adding a stronger acid.

G. *Nitrate of potash is also decomposed by sulphur.* Mix powdered nitre and sulphur, and throw the mixture, by a little at a time, into a red-hot crucible. The sulphur will unite with the oxygen of the nitric acid, and form sulphuric acid; which, combining with the potash, will afford sulphate of potash. The production of the latter salt will be proved by dissolving the mass remaining in the crucible and crystallizing it, when a salt will be obtained exhibiting the characters described.

H. A mixture of three parts of powdered nitre, two of carbonate of potash, or common salt of tartar, and one part of sulphur, all accurately mixed together, forms the *fulminating powder*, which explodes with a loud noise when laid on an iron heated below redness.

I. A mixture of five parts of powdered nitre, one part of sulphur, and one of powdered charcoal, composes *gunpowder*. The materials must all be very finely powdered separately, then mixed up together, and beaten with a wooden pestle, a sufficient quantity of water being added to prevent an explosion. The mixture must afterward be granulated by passing through sieves and dried.

K. *Nitrate of potash is also decomposed by sulphuric acid.* Put some coarsely-pounded nitre into a retort, with half its weight of sulphuric acid, adapt a receiver, and apply heat. The nitric acid will pass over into the receiver, and in the retort will remain a compound of potash and sulphuric acid.

Nitrate of soda is a salt not possessed of any properties that are generally interesting. It may be formed by saturating nitric acid with carbonate of soda, or by distilling common salt (muriate of soda) with nitric acid.

Nitrate of Ammonia.

This salt derives importance chiefly from its application to the purpose of obtaining nitrous oxyd; and, as the method of producing it and of obtaining from it the nitrous oxyd have been already described, it is unnecessary to add here any thing more concerning it.

Muriatic Acid. — Oxygenized Muriatic Acid. — And their Combinations with Alcalis.

1. The muriatic acid, in its purest form, exists in the state of a gas, permanent over mercury only. For exhibiting its properties, therefore, a mercurial apparatus is absolutely necessary.

2. Muriatic acid gas may be obtained, most commodiously, from dried muriate of soda, in a gas-bottle, with half its weight of strong sulphuric acid. It exhibits the following properties:

A. *It has a very pungent smell.*

B. *When brought into contact with common air, it occasions a white cloud.* This is owing to the moisture always present in the atmosphere.

C. *It extinguishes a lighted candle.*

D. *It is very rapidly absorbed by water.* A drop or two of water, admitted to a large jar full of this gas, causes the whole of it instantly to disappear.

3. Water, when charged as highly as possible with this gas, forms the ordinary muriatic acid in a liquid state. This watery solution of muriatic acid has the following properties:

A. *It is heavier than water in the proportion of* 1170 to 1000.

B. *It emits white and suffocating fumes.*

C. *It is not acted on by inflammable substances,* even when considerable heat is applied.

D. *When diluted with water,* no remarkable degree of heat is produced.

E. *It combines with the alcalis,* and constitutes a peculiar genus of neutral salts.

Muriate of Potash.

This salt is not peculiarly interesting.

Muriate of Soda.

Muriate of soda is that well known salt, now become a necessary ingredient in the food of man, and of great utility in several of the arts.

1. Its composition may be proved by the direct union of soda with muriatic acid.

2. Its qualities are as follows:

1. *It requires, for solution, twice and a half its weight of water, at 60° of Faht.* and hot water takes up very little more. Hence its solution crystallizes, not like that of nitre, by cooling, but by evaporation.

B. *When heated gradually it fuses,* and forms when cold a solid compact mass.

C. If suddenly heated, as by throwing it on red-hot coals, it *decrepitates.*

D. *It is not decomposed when ignited in contact with inflammable substances.*

E. *When distilled with sulphuric acid and water,* its acid is disengaged, and there remains in the retort a compound of sulphuric acid with soda.

Muriate of Ammonia.

1. If equal measures of ammoniacal gas (see page 44) and muriatic acid gas be mixed together over mercury, they are immediately condensed, a white cloud is formed, and a solid substance is de-

posited on the sides of the vessel. This is the muriate of ammonia. It properties are as follow:

A. *It is volatilized,* without being decomposed, and hence may be sublimed.

B. *It is readily soluble in water,* three parts and a half of which, at 60°, take up one of the salt. During its solution much caloric is absorbed.

C. *On the addition of a solution of pure potash or pure soda, the alcali is disengaged,* as is evinced by the pungent smell that arises on the mixture of two bodies perfectly inodorous when separate.

D. *From this salt sulphuric acid separates the muriatic acid.* This may be proved by substituting it for common salt, in preparing muriatic acid gas.

Oxygenized Muriatic Acid.

1. This acid may be formed by either of the following processes:

A. Into a stoppered retort introduce eight ounces of liquid muriatic acid, and four ounces of finely-powdered manganese, and apply the heat of a lamp. A gas will be produced, which may be received over water in the usual manner. From the foregoing materials about 160 cubical inches of gas may be obtained.

B. Mix eight ounces of muriate of soda (common salt) with three ounces of powdered manganese; put them into a stoppered retort, and pour on them four ounces of sulphuric acid, diluted previously with four ounces of water, and which has been suffered to cool after dilution. On applying a gentle heat, gas will be produced, as in A. As the gas is absorbed by contact with water, though not rapidly, it should be received, when it is intended to be kept, into bottles filled with, and inverted in, water, and provided with ground stoppers. The stopper must be introduced under water while the bottle remains inverted.

2. This gas has the following properties:

A. *It has a deep yellow colour.*

B. *It has a pungent and suffocating smell.* In experiments on this gas, great care should be taken that it does not escape, in any considerable quantity, into the apartment, as its action on the lungs is extremely injurious and oppressive.

C. By a temperature of 40°, it is reduced into a liquid form, and is condensed on the sides of the vessel. Hence some chemists have contended that it should be classed among vapours and not among gasses.

D. *When a burning candle is immersed in the gas the flame is enlarged and a dense smoke is produced.*

E. *Phosphorus, introduced into it, immediately takes fire* and burns very brilliantly.

F. *Various metals, when minutely divided by filing,* as iron, zinc, bismuth, tin, copper, &c. *take fire in this gas,* and burn with an extrication of heat and light.

G. *Sulphur is oxygenized by it* and changed into sulphuric acid. If a lump of rolled brimstone be fastened to the end of a glass rod and confined in a large bottle of the gas, drops of sulphuric acid will soon begin to fall from it.

H. *Charcoal, finely powdered and perfectly dry, takes fire in this gas.*

I. *The oxygenized muriatic gas destroys all vegetable colours.* This may be shown by passing into it, through water, a piece of cloth, or of paper, stained with litmus, the colour of which will speedily disappear. Hence the application of this gas to the purpose of bleaching. Its efficacy, in this mode, may be seen by confining in it a pattern of unbleached calico.

K. *This gas is absorbed by water;* slowly if allowed to stand over it quiescent, but rapidly when agitated.

L. *The watery solution acquires the colour and peculiar smell of the gas,* and has a similar property of discharging vegetable colours. Hence it may be employed in bleaching.

M. *When the watery solution is exposed to a temperature a little above that of freezing water, the gas which is combined with it separates in the form of a liquid heavier than water.*

N. *When this solution is exposed to the direct rays of the sun, the oxygenized acid is decomposed;* its oxygen escapes in the form of a gas, and it is reduced to the state of common muriatic acid. The oxygenous gas may be collected by exposing the solution in a gas-bottle furnished with a bent tube, which terminates in the pneumato-chemical apparatus.

O. *The oxygenized muriatic acid combines with alcalis,* and forms peculiar compounds.

Hyper-oxygenized Muriate of Potash.

The properties of this salt were discovered by Berthollet. It may be formed by passing the oxygenized muriatic gas, as it proceeds from the mixture of muriate of soda, sulphuric acid, and manganese, through a solution of caustic potash. This may be done by means of Woulfe's apparatus, using only one three-necked bottle in addition to the balloon. The tube which is immersed in the alcaline solution should be at least half an inch in diameter, to prevent its being choked up by any crystals that may form. The solution, when saturated with the gas, may be gently evaporated, and the first products only of crystals are to be reserved for use; for the subsequent products consist of common muriate of potash only. Now, since the gas, when it first came into contact with the alcaline solution, was purely oxygenized muriatic acid, it follows that a part of this acid must have been disoxygenized during the absorption, and have returned back to the state of common muriatic acid. Let us suppose the oxygenized acid, when first presented to the alcaline solution, to be divided into two portions; one of these gives up its excess of oxygen to the other half, returns to the state of common muriatic acid, and, combining with the alcali, forms muriate of potash. The latter portion, therefore, is oxygenized acid, plus a certain quantity of oxygen, and this, uniting with another portion of alcali, forms a salt which Mr Chenevix has termed hyper-oxygenized muriate. Strictly speaking, simple oxygenized muriates do not exist; for, in all this class of salts, the acid contains 65 per cent. of oxygen more than in the state of common muriatic acid; whereas, the oxygenized acid contains only 16 per cent. in addition. It might be expected that a stronger acid, such as the sulphuric, would expel from these salts the hyper-oxygenized acid in the form of gas; but this acid, by the temperature necessary for its liberation, is partially decomposed, and again returns nearly to the state of oxygenized acid.

The reader who wishes for farther information on this subject is referred to a masterly paper of Mr Chenevix, in the Phil. Trans, 1801; reprinted in Nicholson's 8vo Journal, vol. i. and in the Phil. Mag.

The hyper-oxygenized muriate of potash has the following qualities:

A. *It has the form of shining hexaedral laminæ or rhomboidal plates.*

B. *One part of the salt requires* 17 *of cold water for solution; but* 5 *parts of hot water take up* 2 *of the salt.*

C. *When the hyper-oxygenized muriate is submitted to distillation, in a coated retort, it first fuses, and, on a farther increase of temperature, yields oxygenous gas of great purity.* A hundred grains of salt afford 75 cubic inches of gas.

D. *The hyper-oxygenized muriate of potash has no power of discharging vegetable colours;* but the addition of a little sulphuric acid, by setting the oxygenized acid at liberty, developes this property.

E. *The salt is decomposed by the stronger acids, as the sulphuric and nitric acids.* This will be proved by dropping a few grains of the salt into a little strong sulphuric acid. A strong smell will arise, and, if the quantities be sufficiently large, an explosion will ensue. The experiment should, therefore, be made with caution. When this mixture is made at the bottom of a deep vessel, the vessel is filled with oxygenized muriatic gas, which inflames sulphuric ether, alcohol, or oil of turpentine, when poured into it; and also camphire, resin, tallow, elastic gum, &c. (Davy.)

F. *This salt exerts powerful effects on inflammable bodies.* (a) Rub two grains into powder in a mortar, and add one grain of sulphur. Mix them very accurately, by gentle triture, and then, having collected the mixture to one part of the mortar, press the pestle down upon it suddenly and forcibly. A loud detonation will ensue. Or, if the mixed ingredients be wrapped in some strong paper and then struck with a hammer, a still louder report will be produced.

(b) Mix five grains of the salt with half the quantity of powdered charcoal in a similar manner. On triturating the mixture strongly, it will inflame, especially with the addition of a grain or two of sulphur, but not with much noise.

(c) Mix a small quantity of sugar with half its weight of the salt, and on the mixture pour a little strong sulphuric acid. A sudden and vehement inflammation will be produced. This experiment, as well as the following, requires caution.

(d) To one grain of the powdered salt, in a mortar, add about half a grain of phosphorus. The phosphorus will detonate, on the gentlest triture, with a very loud report. The hand should be covered with a glove in making this experiment, and care should be taken that the phosphorus, in an inflamed state, does not fly into the eyes. Phosphorus may also be inflamed under the surface of water by means of this salt. Put into a wine-glass, one part of phosphorus with two of the salt; fill it nearly with water, and pour in, by means of a glass tube reaching to the bottom, three or four parts of sulphuric acid. The phosphorus takes fire and burns vividly under the water. This experiment requires caution lest the inflamed phosphorus should be thrown into the eyes. (Accum.) Oil may also be thus inflamed on the surface of water, the experiment being made with the omission of the phosphorus and the substitution of a little olive or linseed oil.

(e) Hyper-oxygenized muriate may be substituted for nitre in the preparation of gunpowder, but the mixture of the ingredients requires great circumspection. It may be proper also to state that this salt should not be kept mixed with sulphur in considerable quantity, such mixtures having been known to detonate spontaneously.

Hyper-oxygenized Muriate of Soda.

This salt has no remarkable properties. It differs from the combination of this acid with potash in attracting moisture from the atmosphere.

With ammonia, the oxygenized muriatic acid does not afford any combination, but decomposes this alcali when brought into contact with it, whether in a gaseous or liquid state. Westrumb has even asserted, that, when liquid ammonia is poured into a vessel filled with oxygenized muriatic gas, an inflammation ensues. This appearance, however, I could never produce. The decomposition of ammonia, by oxygenized muriatic acid, is best exhibited by passing the gas through a bottle filled with a watery solution of ammonia, and having two openings, from one of which a bent tube passes to the pneumato-chemical apparatus, while the other receives the tube that brings the acid gas. The gas that is produced will be found to be azotic. The theory of this decomposition will be explained on a subsequent occasion.

This property of ammonia renders it extremely useful in correcting the offensive vapours of the gas, which are sometimes accidentally set at liberty in places where it is prepared. And, when suffocation threatens to come on, in consequence of the fumes of this acid, the most effectual remedy is to hold a stopper, moistened with ammonia, to the mouth and nostrils. From recent experiments of Mr Chenevix, it appears, that the hyper-oxygenized muriat of ammonia may be formed by precipitating any of the earthy salts of this genus with a solution of carbonate of ammonia.

Nitro-Muriatic Acid.

This acid is a compound of the nitric and muriatic acid, and may be formed by mixing two parts of nitric acid with one of muriatic, and by several other processes, which are pointed out in every elementary book. Its most distinguishing property, that of dissolving gold, will be described hereafter.

Art. XV. — *Phosphorus, — Phosphoric Acid, — Phosphates.*

1. *Phosphorus is an inflammable substance, and is known by the following characters:*

A. It has generally a flesh red colour, but, when carefully purified, may be obtained as free from colour and as transparent as melted white wax.

B. It is so soft that it readily yields to the knife.

C. It melts with a very gentle heat. To show this, it must be covered with water, to prevent it from inflaming.

D. In the atmosphere, it emits a white smoke and peculiar smell and a faint and beautiful light arises from it.

2. *Phosphorus is inflamed by the application of a very gentle heat.* According to Dr Higgins, a temperature of 60° is sufficient to set it on fire, when perfectly dry. It burns with a very brilliant light, a white smoke, and a suffocating smell.

3. *It may be set on fire by friction.* Rub a very small bit between two pieces of brown paper; the phosphorus will inflame, and will set the paper on fire also.

4. *In oxygenous gas it burns with a very beautiful light;* and also in nitrous oxyd and in oxygenized muriatic acid.

5. *Phosphorus is volatile.* Hence it may be raised by distillation; but, to prevent its taking fire on the application of heat, the retort should previously be filled with azotic or hydrogen gas, and the mouth of the retort must be immersed in water. A bladder should also be provided, furnished with a stop-cock and brass pipe, and filled with hydrogen gas. During the distillation, the air in the retort is absorbed, and it is necessary to add more from the bladder, otherwise the water will rush into the retort and occasion an

explosion. By distillation in this mode, phosphorus is rendered much purer.

6. *Phosphorus may be oxygenized in various modes.*

A. By mere exposure to atmospheric air. Let a stick of phosphorus be placed in a funnel, the pipe of which terminates in an empty bottle. The phosphorus will be slowly oxygenized, and, after some time, will be wholly changed into an acid, which will fall into the bottle in a liquid state.

B. By combustion in oxygenous gas or atmospheric air. When burnt in this manner, every hundred parts of phosphorus, according to Lavoisier, gain an addition of 154. See the account of this experiment in the 5th chapter of his Elements.

C. By the nitric acid. If phosphorus be added, by little at once, to nitric acid, heated in a mattress, the nitric acid is decomposed, and its oxygen, uniting with the phosphorus, constitutes phosphoric acid.

D. A similar effect is produced by oxygenized muriatic acid in a liquid state. The operation of this acid, in a gaseous form, is described page 86, E.

Accordingly as the phosphoric acid is differently prepared, its degree of oxygenation differs, and its properties are found to vary proportionably. That formed by the spontaneous oxygenation of phosphorus in air, is termed phosphorus acid, as being oxygenated in an inferior degree, and its compounds are called phosphites; but these last, it may be observed, can scarcely be obtained, because the phosphorus acid, when combined with alcalis, acquires an addition of oxygen during evaporation.

Phosphoric Acid.

To prepare this acid, the following is the best process:

On 20 pounds of bones, calcined to whiteness and finely powdered, pour 20 quarts of boiling water, and add eight pounds of sulphuric acid diluted, with an equal weight of water. Let these materials be well stirred together and be kept in mixture about 24 hours. Let the whole mass be next put into a conical bag of sufficiently porous and strong linen, in order to separate the clear liquor, and wash it with water till the water ceases to have much acidity to the taste. Evaporate the strained liquor in earthen vessels, placed in a sand-heat, and, when reduced to about half its bulk, let it cool. A white sediment will form in considerable quantity, which must be allowed to subside; the clear solution must be decanted and boiled to dryness in a glass vessel. A white mass will remain, which is the dry phosphoric acid. This may be fused in a crucible and poured out on a clean copper dish. A transparent glass is obtained, which is the phosphoric acid in a glacial state; not, however, perfectly pure, but containing sulphate and phosphate of lime.

To procure the phosphoric acid perfectly pure, the decomposition of phosphorus, by nitric acid, is the most eligible process. (C. of the preceding article.) The undecomposed nitric acid must be separated by distillation in a glass retort, and the dry mass, when fused, affords also glacial phosphoric acid.

The phosphoric acid has the following properties:

A. When pure it dissolves readily in water. That obtained immediately from bones is rendered insoluble by the admixture of earthy salts. But the glacial acid, prepared with nitric acid, is readily soluble.

B. *It is not volatile, nor capable of being decomposed by heat only.*

C. *When distilled in an earthen retort with powdered charcoal it is decomposed*; its oxygen, uniting with the carbon, forms carbonic acid, and the phosphorus rises in a separate state. This is the usual and best mode of obtaining phosphorus.

D. *Phosphoric acid unites with the different alcalis, and formsa class of salts termed phosphates*; — of these the phosphate of soda is the most important one, since its introduction into medicine by Dr Pearson, and the phosphate of ammonia is occasionally used as a flux for the blow-pipe.

Another combination of phosphorus, the properties of which render it a fit subject of amusing experiments, is the

Phosphuretted Hydrogenous Gas.

1. *This gas may be procured* by boiling, in a retort, a little phosphorus with a solution of pure potash. The water is decomposed; its oxygen uniting with the phosphorus, forms phosphoric acid, which combines with the alcali, while the hydrogen dissolves another portion of phosphorus, constituting phosphorated hydrogen gas. It may also be obtained by putting into five parts of water half a part of phosphorus, cut into very small pieces, with one of finely granulated zinc, and adding three parts of strong sulphuric

acid. This affords a pretty experiment. The gas is disengaged in small bubbles, which cover the whole surface of the fluid, and takes fire on reaching the air; these are succeeded by others, and a well of fire is produced. (Davy.)

In preparing this gas, the body of the retort should be filled, as nearly as possible, with the alcaline solution; otherwise the gas, when produced, will inflame and diminish the air within the retort, and the water will ascend from the trough. This accident may be effectually prevented by previously filling the retort with azotic gas.

2. The properties of this gas are the following:

A. *It takes fire immediately on coming into contact with the air.* This may be shown by letting it escape into the air, as it issues from the retort, when a very beautiful appearance will ensue.

B. *When mixed suddenly with oxygen gas it detonates.* — This experiment should be made cautiously.

C. *The same phenomenon ensues on mixing it with oxygenated muriatic acid gas, or with nitrous oxyd.*

Phosphorus is also soluble in oils; and, when thus dissolved, forms what has been called liquid phosphorus, which may be rubbed on the face and hands without injury. It dissolves too in ether, and a very beautiful experiment consists in pouring this phosphoric ether in small portions, and in a dark place, on the surface of hot water.

The phosphoric matches consist of phosphorus extremely dry, minutely divided, and perhaps a little oxydated. The simplest mode of making them is to put a little phosphorus, dried by blotting paper, into a small phial; heat the phial, and, when the phosphorus is melted, turn it round so that it may adhere to the sides. Cork the phial closely, and it is prepared. On putting a common sulphur match into the bottle, and stirring it about, the phosphorus will adhere to the match, and will take fire when brought out into the air.

ART. XVI. — *Boracic Acid and its Combinations.*

The Boracic acid is very rarely found native, and is generally the result of chemical operations. Its properties are as follow.

A. *It subsists in a solid state.*

B. *Unlike acids in general, it is not distinguished by a sour taste,* yet it reddens vegetable blue colours, and effervesces with carbonated alcalis.

C. *It is very sparingly soluble in water, but more copiously in hot than in cold water.*

D. *It is volatile, and capable of being sublimed.*

E. *It dissolves in small proportion in alcohol, and the solution burns with a beautiful green flame.*

F. *It combines with alcalis.* The most important of its combinations is that with soda, known commonly by the name of borax. From this it may be separated by adding sulphuric acid, which forms sulphate of soda, a salt much more soluble than the boracic acid, and therefore easily separable from it.

G. *The borate of soda* contains an excess of alcali, and hence changes vegetable blue colours to green. On the application of a strong heat, it swells and loses its water of crystallization; and, on a farther increase of heat, it melts into a glass, which is perfectly transparent when cold.

ART. XVII. — *Earths.*

Lime.

1. *Its external qualities.* These may be exhibited in common quicklime, such as is employed for the purposes of building or agriculture. In the same state it is sufficiently pure for demonstrating its chemical properties; but, when used for purposes of the latter kind, it should be fresh burnt from the kiln.

Relation of lime to water.

A. Lime absorbs water very rapidly with considerable heat and noise. This may be shown by sprinkling a little water on some dry quicklime. The above-mentioned phenomena will take place, and the lime will fall into powder. The degree of heat produced is even sufficient to set fire to some inflammable bodies. When a sufficient quantity of water has been added to reduce lime into a thin paste, this is called milk or cream of lime.

B. Lime absorbs moisture from the atmosphere and falls gradually into powder, as when slaked in the foregoing manner.

C. Lime is very sparingly soluble in water, viz. in the proportion of about 1 to 500; and, when thus dissolved, forms what has been termed lime-water. This solution tastes of lime, turns vegetable blues to green, and unites with oil, forming an imperfect soap. To prepare the solution, lime is to be slaked to a thin paste, and a sufficient quantity of boiling water afterwards added.—The mixture is to be stirred repeatedly, the lime allowed to settle, and the clear liquor decanted for use. It must be preserved in close vessels.

3. *Relation of lime to inflammable substances.*

A. Lime unites with *sulphur*, both in the dry and humid ways. Mix powdered lime with half its weight of sulphur, and expose them to heat in a covered crucible. The product will be a sulphuret of lime, which will be found to have the property of diminishing atmospheric air and absorbing oxygenous gas like other compounds of the same kind. Or boil in a glass vessel, with a sufficient quantity of water, some powdered sulphur and powdered lime. The lime and sulphur will unite and a liquid sulphuret of lime will be obtained.

B. Another interesting combination of lime is that which it forms with *phosphorus*, or the phosphuret of lime discovered by Dr. Pearson. Take a glass tube, about 12 inches long and $\frac{1}{3}$ of an inch diameter, sealed hermetically at one end. Let this tube be coated with clay, except within about half an inch of the sealed end. Put first into it a drachm or two of phosphorus, cut into small pieces, and then fill the tube with small bits of fresh burnt lime of the size of split peas. Stop the mouth of the tube loosely with a little paper, in order to prevent the free access of air. Next, heat to redness that part of the tube which is coated with clay by means of a chafing-dish of red hot charcoal; and, when the lime may be supposed to be ignited, apply heat to the part containing the phosphorus so as to sublime it and to bring the vapour of it into contact with the heated lime. The lime and phosphorus will unite, and will afford a compound of a reddish brown colour. The phosphuret of lime has the remarkable property of decomposing water at the common temperature of the atmosphere. Drop a small piece of it into a wine-glass of water, and in a short time bubbles of phosphorated hydrogen gas will be produced; which, rising to the surface, will take fire and explode. If the phosphuret of lime be not perfectly fresh, it may be proper to warm the water to which it is added.

Into an ale-glass put one part of phosphuret of lime, in pieces about the size of a pea (not in powder), and add to it half a part of hyper-oxygenized muriate of potash. Fill the glass with water, and put into it a funnel with a long pipe or narrow glass tube reaching to the bottom. Through this pour three or four parts of strong sulphuric acid, which will decompose the hyper-oxygenized salt; and the phosphuret also decomposing the water at the same time, flashes of fire dart from the surface of the fluid, and the bottom of the vessel is illuminated by a beautiful green light. (Davy.)

4. *Relation to acids.*

A. Lime has a strong attraction for *carbonic acid,* but not when perfectly dry. (a) If a piece of dry quicklime be passed into a jar of carbonic acid gas over mercury, no absorption ensues. But invert a bottle, filled with carbonic acid gas, over a mixture of lime and water of the consistence of cream, and a rapid absorption will be observed, especially if agitated.

(b) Let a jar or bottle, filled with carbonic acid, be brought over a vessel of lime-water. On agitating the vessel, a vapid diminution will ensue, and the lime-water will become milky.

(c) Leave a shallow vessel of lime water exposed to the air. A white crust will form on the surface, and this, if broken, will fall to the bottom, and be succeeded by another. This is owing to the absorption of carbonic acid gas from the air, by the lime, which is thus rendered insoluble in water.

(d) Lime, when exposed to the atmosphere, first acquires moisture and then carbonic acid; and, in a sufficient space of time, all the characters distinguishing it as lime disappear.

(e) Lime has an extremely strong affinity for carbonic acid, which enables it to take this acid from other substances. Thus carbonates of alcalis are decomposed by lime. Slake a given quantity of lime into a paste with water, and add an equal weight of carbonate of potash or soda. Stir the materials together and wash off the soluble part. The carbonic acid combines with the lime, and the alcali is obtained in a state of solution perfectly free from carbonic acid. This is the ordinary mode of depriving the alcalis of carbonic acid.

(f) Lime, when saturated with carbonic acid, forms carbonate of lime. Of this common chalk may be taken as a fair sample; and, in all saturated carbonates of this earth, we find the characters of insipidity and insolubility in water.

(g) Carbonate of lime is decomposed by a strong heat. If distilled in an earthen retort, carbonic acid gas is obtained, and lime remains in the retort in a pure or caustic state.

(h) It is also decomposed by the stronger acids. Put some chalk into a gas-bottle and pour on it diluted sulphuric acid. The sulphuric acid will unite with the lime and the carbonic acid will be set at liberty.

(i) Carbonate of lime, though scarcely dissolved by pure water, is soluble in water saturated with carbonic acid. The most striking method of showing this is the following: Add to a jar, about one fourth filled with lime water, a very small quantity of water saturated with carbonic acid. An immediate milkiness will ensue, because the carbonic acid forms with the lime an insoluble carbonate. Add gradually more of the water, impregnated with carbonic acid, shaking the jar as these additions are made. At last the precipitate is redissolved. Hence it appears that lime, with a small proportion of carbonic acid, is insoluble, and, with a still larger, again becomes soluble in water.

(k) The carbonate of lime, dissolved by an excess of carbonic acid, is again separated, when this excess is driven off. Thus, boiling, which expels the superabundant acid, precipitates the carbonate. Caustic or pure alcalis also produce a similar effect.

B. Combination of lime with *sulphuric acid*, or sulphate of lime.

(a) The sulphuric acid expels the carbonic from lime, and we obtain a sulphate of lime.

(b) This substance is very insoluble, requiring 500 parts of water, at the ordinary temperature, for solution.

(c) It is insipid and free from smell.

(d) It is fusible by a gentle heat.

(e) It is decomposed when its solution is mixed with one of carbonate of alcali, a double exchange of principles ensuing. Hence the milkiness on adding an alcali to most spring waters, the carbonate of lime which is formed being less soluble than the sulphate.

C. Combination of lime with *nitric acid.* This compound forms a deliquescent salt of little importance.

D. Combination with *muriatic acid.*

(a) Lime may be brought into union with muriatic acid by dissolving in the liquid acid either the pure earth or the carbonate.

(b) The muriate of lime may also be formed by boiling together, in a retort, the muriate of ammonia and lime with water. The lime sets the alcali at liberty, which may be collected in a liquid form in a receiver, and the muriate of lime remains in the retort.

Or it may be obtained from muriate of ammonia and carbonate of lime, in which case we obtain the carbonate of ammonia. For this purpose, powdered sal ammoniac and dry carbonate of lime may be mixed together, and put into a glass or earthen retort with a long neck. This neck may terminate in a large glass globe, which should be kept cool by moistened cloth. The carbonate of ammonia will pass over in a solid form, and will condense on the inner surface of the globe.

(c) Muriate of lime, when evaporated to the consistence of a thick sirup, forms, on cooling, an imperfectly crystallized mass, which may be powdered and reserved for use.

(d) It powerfully attracts moisture from the air, and hence should be kept closely stopped up.—Like all other deliquescent salts, it is very soluble in water.

(e) The most remarkable property of this salt is its power of generating intense cold when mixed with snow. This property was discovered some years ago by M. Lovitz, of St. Petersburgh, and has been since applied, in this country, to the congelation of mercury on a very extensive scale.—The proportions, which answer best, are about equal weights of the salt finely powdered and of fresh fallen and light snow. On mixing these together and immersing a thermometer, in the mixture, the mercury sinks with great rapidity. For measuring exactly the cold produced, a spirit-thermometer should be employed. A few pounds of the salt are sufficient to congeal a large mass of mercury. By means of 13 lbs of the muriate and an equal weight of snow, Messrs Pepys and Allen froze 56 lbs of quicksilver into a solid mass. The mixture of the whole quantity of salt and snow, however, was not made at once, but part was expended in cooling the materials themselves. On a small scale it may be sufficient to employ 2 or 3 pounds of the salt. Let the mercury, in a very thin glass retort, be immersed first in a mixture of one pound of each; and, when this has ceased to act, let another mixture be prepared. The second will never fail to congeal the quicksilver.

The salt thus expended may be again evaporated and crystallized for future experiments.

The reader, who wishes for farther particulars respecting these experiments, is referred to the Philosophical Magazine, vol. 3, p. 76.

E. Lime unites with the *phosphoric acid.*

The phosphate of lime forms a large part of animal bones, which, to obtain their earthy part, must be burnt till perfectly white.

The phosphate of lime is an insipid and insoluble salt, or rather earth. It is decomposed by sulphuric acid, which sets the phosphoric at liberty. This is the common mode of procuring phosphoric acid from bones.

The phosphate of lime exists in two states: in the one, the constituents exactly saturate each other; in the second, the phosphoric acid is in excess. The latter is much more soluble in water.

F. *Fluate* of lime. This is also an extremely insoluble compound. The fluor spar, found in Derbyshire and other places, is the only known source of it.—Sulphuric acid decomposes the fluate; and, when distilled with this acid, in a leaden or block-tin retort, the fluoric acid rises, and may be collected in a leaden or tin receiver.

This acid, when perfectly pure, subsists in the state of a gas condensible by water. It is the only acid that acts on siliceous earth and on glass; and, owing to the latter property, it may be employed as a mean of etching on glass, as copper is engraved by the nitric acid. See Wilson's paper in Nicholson's Journal, vol. 2, p. 60.

Magnesia.

1. *Pure magnesia is white, perfectly tasteless, insoluble in water, and excites no heat when mixed with water.*

2. When exposed to *carbonic acid gas*, with the addition of a little water, the gas is absorbed, but much more slowly than by lime.

Carbonate of magnesia effervesces with acids, its carbonic acid being expelled. When exposed to heat, its carbonic acid is also separated and the magnesia remains pure. In this state it is termed *calcined magnesia.*

Carbonic acid having a stronger affinity for lime than for magnesia, when carbonate of magnesia is digested with lime water, the lime attracts the carbonic acid from the magnesia and is rendered insoluble. Hence the taste of lime water is totally destroyed by carbonate of magnesia.

3. *Magnesia combines with sulphuric acid.* When concentrated sulphuric acid is poured on pure magnesia, a great degree of heat is produced; and, when the two ingredients are perfectly pure, ignition even ensues.

The combination of magnesia with sulphuric acid affords a neutral salt, termed *sulphate of magnesia.* This salt forms small crystals, which have a cool bitter taste, and dissolve readily in water. It is decomposed by pure and carbonated alcalis. If a solution of a pound of the salt in a pound of boiling water be mixed suddenly with a solution of an equal quantity of carbonate of potash, in the same weight of water, a double decomposition ensues, and the two fluids instantly form a thick solid coagulum. This, when well washed with boiling water, affords the carbonate of magnesia.

The compounds of magnesia with other acids have no properties that render it necessary to describe them in this place.

Alumine, or Argill.

Alumine may be obtained free from other earths, but still combined with carbonic acid by precipitating a solution of alum in water by the crystallized carbonate of potash. To secure its complete purification from sulphuric acid, Guyton advises that the precipitate be redissolved in nitric acid, that nitrate of barytes be cautiously added to the solution, till it no longer occasions milkiness, and that the alumine be afterwards precipitated, or separated from the nitric acid by heat. (Ann. de Chim. xxxii. 64.)

2. *Alumine has the following qualities.* It adheres to the tongue; when moistened with water it forms a cohesive mass; and, when heated to redness, it shrinks considerably in bulk and becomes very hard. It dissolves slowly in all acids. The only combination of importance is that which it forms with the sulphuric acid.

3. *With sulphuric acid it affords sulphate of alumine or alum.*

Sulphate of alumine is distinguished by the following characters.

A. It has a sweetish astringent taste.

B. It dissolves in water, 5 parts of which, at 60°, take up one of the salt, but hot water dissolves about $\frac{3}{4}$ths of its weight.

C. This solution reddens vegetable blue colours; which proves the acid to be in excess.

D. When mixed with a solution of carbonate of potash, an effervescence is produced by the uncombined acid, which also prevents the first portions of alcali, that are added to a solution of sulphate of alumine, from occasioning any precipitate.

E. On a farther addition of alcali, the alumine is precipitated.

F. Sulphate of alumine, when heated, swells up, loses its regular form, and becomes a dry spungy mass; but, according to Vauquelin, (37 Ann. de Chim. p. 91,) the whole of its acid cannot thus be expelled.

G. The combination of sulphuric acid with alumine is incapable of crystallizing without an admixture of sulphate of potash, which forms a constituent of all the alum of commerce. According to Vauquelin, 100 parts consist of 49 dry sulphate of alumine, 7 sulphate of potash, and 44 water.

H It is decomposed by charcoal, which combines with the oxygen of the sulphuric acid, and leaves the sulphur attached to the alumine. A combination of alumine, sulphur, and charcoal, forms the *pyrophorus of Homberg*. To prepare this, equal parts of powdered alum and brown sugar are melted over the fire, and are kept stirring till reduced to dryness. The mixture is then to be finely powdered, and introduced into a common phial, coated with clay, to which a glass tube, open at each end, is luted, to allow the escape of the gasses that are produced. The phial must then be set in the fire, surrounded by sand, in a crucible. Gas will issue from the open end of the tube, and may be inflamed by a lighted paper. When this ceases to escape, the crucible may be removed from the fire, and a little moist clay pressed down upon the open end of the tube, to prevent the access of air to the contents of the phial.

The pyrophorus thus formed is a black and very light powder, which instantly takes fire when poured out of the bottle into the air, and inflames suddenly in oxygenous gas.

Silex.

1. Siliceous earth, or silex, may be obtained tolerably pure from flints by the following process. Procure some common gun-flints, and calcine them in a crucible in a red heat. By this treatment they will become brittle, and easily reducible to powder. Mix them, when pulverized, with three or four times their weight of carbonate of potash, and let the mixture be fused in a strong red heat, in a crucible. We shall thus obtain a compound of alcali and siliceous earth. Dissolve this in water, filtre the solution, and add to it diluted sulphuric or muriatic acid. An immediate precipitation will ensue, and, as long as this continues, add fresh portions of acid. Let the precipitate subside, pour off the liquor that floats above it, and wash the

sediment with hot water, till it comes off tasteless. Then dry it.

2. Siliceous earth, as thus obtained, has the following qualities:

A. It is perfectly white and tasteless.

B. When mixed with water it does not form a cohesive mass like alumine, and has a dry and harsh feel to the fingers.

C. It is not acted on by any acid except the fluoric.

D. When prepared in the foregoing manner, and very minutely divided, silex is taken up by a solution of pure potash. In the aggregated state of flints, however, it is perfectly insoluble in this way, an excellent illustration of the principle laid down, Art. I. No. 3.

E. When mixed with an equal weight of carbonate of potash, and exposed to a strong heat in a furnace, it forms a glass, insoluble in water, and identical in all its properties with the glass commonly manufactured. It is owing to the siliceous earth which it contains that glass is decomposed by the fluoric acid. Glass, however, has occasionally other ingredients besides the two that have been mentioned.

F. With a larger proportion of alcali, as three or four parts to one of silex, this earth affords a compound called, by Dr Black, *silicated alcali*. This compound is soluble in water, and affords a good example of the total change of the properties of bodies by chemical union; for, in a separate state, no substance whatever is more difficult of solution than silex *. The solution of silicated alcali was formerly termed *liquor silicum*, or *liquor of flints*. Acids seize the alcali, and precipitate the silex, which is even separated by mere exposure to the atmosphere, in consequence of the absorption of carbonic acid by the alcali.

Barytes.

1. Barytes, in a pure form, has a sharp caustic taste, changes vegetable blues to green, and serves as the intermedium between oil and water.

2. It is readily dissolved by boiling water, and the solution, on cooling, shoots into regular crystals, which have the form of flattened hexagonal prisms, having two broad sides, with two intervening narrow ones, and terminated at each end by a qnadrangular pyramid.

3. These crystals are so soluble as to be taken up, when heated, merely by their own water of crystallization. Hence barytes, and strontites also, on the same grounds, may, with equal, and perhaps greater, propriety, be arranged among the alcalis; an arrangement adopted by Fourcroy in his Système. When exposed to a stronger heat, they swell and foam, and leave a dry white powder. At 60°, an ounce of water dissolves only 25 grains of the crystals.

4. Pure barytes has a very strong affinity for *carbonic acid.*

---

* On the solubility of silex in water, consult Klaproth's Contributions, p. 399, 400.

A. Let a solution of pure barytes be exposed to the air. It will soon acquire a pellicle, like lime water, because barytes, when saturated with carbonic acid, is rendered insoluble.

B. Blow, by means of a quill or glass tube, the air from the lungs, through a solution of pure barytes. It will instantly become milky.

C. With a solution of pure barytes, mix a little water impregnated with fixed air. The barytic solution will be immediately precipitated.

D. Barytes, combined with carbonic acid, is termed carbonate of barytes. If this combination be found in the earth, it is termed native carbonate of barytes, if formed by chemical processes, artificial carbonate.

E. The carbonate of barytes is tasteless, insoluble in water, and does not change vegetable blues.

F. Carbonate of barytes is decomposed by exposure to an intense heat. Its carbonic acid is separated, and we obtain the earth in a pure form, as described, No. I.

G. Carbonate of barytes is decomposed by the stronger acids, as the sulphuric, nitric, and muriatic. The two last afford salts that dissolve readily in water.

5. With sulphuric acid, barytes forms the *sulphate of barytes*.

A. To a solution of pure barytes, add sulphuric acid. A white precipitate will appear, which is the sulphate of barytes.

B. The same compound is formed by adding sulphuric acid to carbonate of barytes, or to a solution of muriate or nitrate of barytes.

C. The sulphate of barytes is one of the most insoluble substances that chemistry presents, requiring, for solution, 43000 times its weight of water.

D. Barytes has a stronger affinity than any other body for sulphuric acid.

E. Owing to these properties, the solution of pure barytes, and of the nitrate and muriate of barytes, are excellent and very sensible tests of sulphuric acid and of all its combinations. Let a single drop of sulphuric acid fall into a wine quart of pure distilled water. On adding a few drops of one of the foregoing solutions of barytes, a precipitation will ensue.

F. Sulphate of barytes is decomposed by carbonate of potash. Boil the powdered sulphate with a solution of twice or three times its weight of carbonate of potash. The carbonic acid will pass to the barytes, and the sulphuric to the potash.

Strontites *.

1. Strontites, in a state of purity, has a caustic taste, changes vegetable blues to green, and unites oil with water.

2. It dissolves very readily in boiling water, and the solution, on cooling, shoots into regular crystals. These are thin quadrangular plates, sometimes square, oftener parallelograms, not exceeding in length, and not equalling in breadth, a quarter of an inch. Of

---

* I use this name after Dr Hope, who first established the peculiar nature of this earth (though before suggested by Dr Crawford), and who discovered its very interesting properties in a state of purity, as well as those of barytes. (See his memoir in the fourth vol. of Edinburgh Transactions.)

these crystals, one ounce of water at 60° takes up only 25 grains. When exposed to heat they undergo the same changes as those of barytes.

3. Pure strontites strongly attracts carbonic acid. This may be shown by experiments similar to those on barytes. Indeed the properties of this earth are so similar to those of barytes, that every thing which has been said of the latter will apply to strontites.

4. The characteristic distinctions between the two earths are derived from the different forms of the crystals, and different solubility of the salts, afforded by their union with the same acid. The salts, with base of strontites, are always much more soluble than barytic salts. The salts of strontites have also the singular property, when dissolved in alcohol, of tinging its flame a deep blood-red colour.

The remaining earths (viz. yttria, glucina, zirconia, and agustina,) I omit, because they very seldom occur, and are not likely to become the subjects of experiment to the chemical student. They may be found enumerated and described in Mr Parkinson's Chemical Pocket-Book.

ART. XVIII. — *Metals in general.*

The most interesting quality, general to all the metals, is their relation to oxygen.

1. Some metals are oxydated merely by exposure to atmospherical air, at the ordinary temperature. Such are arsenic and manganese.

2. Other metals are oxydated by exposure to air, but not without a considerable increase of their temperature. Iron, zinc, copper, tin, &c. for example,

when made red-hot, lose their metallic brilliancy, and are converted into oxyds of different colours.

3. Other metals are not oxydated, even by the combined operation of air and of an increased temperature, such are gold and platina.

4. But even these metals (and all others more readily) are oxydated by acids, Thus the nitro-muriatic and oxygenated muriatic acids first oxydate gold, and then dissolve the oxyd. Iron is oxydated by dilute sulphuric acid, the metal attracting oxygen from the water, and the oxyd of iron, thus produced, is dissolved by the acid.

5. All metals that are oxydated by air undergo the same change much more readily in oxygenous gas.

6. Some metals are oxydated by water, both at the ordinary temperature of the air and in high temperatures. Thus iron-filings, moistened with water, become oxyded, in consequence of its decomposition; and the vapour of water, passed over red-hot iron, is rapidly decomposed, and the iron gains 28 per cent of oxygen. Other metals, as gold, silver, &c. are not oxydated by water in any temperature.

7. All metals, in consequence of oxydation, acquire weight. 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, taking care that dust or ashes do not fall into it.

8. Metals retain oxygen with different degrees of force. Some oxyds (that of mercury for instance) are reduced to a metallic state by heat only; but others (as that of iron) require the addition of some substance that attracts oxygen more strongly than the metal re-

tains it. Thus, to reduce the oxyd of iron, charcoal must be added.

9. Metals are precipitated from acids, by each other, not in the form of oxyds, as they are separated by alcalis, but in a metallic form. Thus, when a polished plate of iron is immersed in a solution of sulphate of copper, the copper appears on the surface of the iron in a state of metallic coating. In this case, the iron attracts the oxygen from the copper; and, as no metal is soluble in an acid, unless when combined with oxygen, the copper is precipitated.

ART. XIX. — *Gold.*

1. Gold may be melted by a moderate red heat.

2. Pure gold is not oxyded by exposure to heat with the access of air.

3. It is not acted on by sulphuric, nitric, or muriatic acid, even at the boiling temperature.

4. It is dissolved, however, by nitro-muriatic acid, and also by the oxygenated muriatic acid. A thin sheet of gold introduced into the latter acid, when in a gaseous state, takes fire and burns.

5. The nitro-muriate of gold gives a purple stain to the skin, and is susceptible of crystallization.

6. It is decomposed by alcalis. A solution of pure ammonia separates an oxyd of gold, and a portion of ammonia, uniting with the oxyd, forms a compound which detonates very loudly in a gentle heat, and is termed *fulminating gold.* It may be exploded by laying a little on a shovel, and applying a very gentle heat over a fire.

7. The solution of gold is also decomposed by certain combustible bodies, which attract the oxygen from the gold and render it insoluble. (A) Into a dilute solution of gold *, contained in a glass jar, put a long narrow slip of charcoal, and expose the whole to the direct light of the sun. The gold will be revived, and will appear on the charcoal in a metallic state, exhibiting a very beautiful appearance. The same change ensues without light, if the solution be exposed to a temperature of 212 °.

B. Moisten a piece of white taffeta ribband, with the dilute solution of gold, and expose it to a current of hydrogen gas from iron filings and dilute sulphuric acid. The gold will be reduced, and the ribband will be gilt with the metal. By means of a camel's hair pencil, the gold may be so applied as to exhibit regular figures, when reduced.

C. The same experiment may be repeated, substituting phosphorated hydrogen for common hydrogen gas. The reader, who wishes for a detail of various experiments of a similar kind, may consult an Essay on Combustion, by Mrs Fulhame, published by Johnson, London, 1794, and also Count Rumford's paper, in the Phil. Trans. 1798, p. 449.

8. When a sheet of tin is immersed in a solution of nitro-muriate of gold, the oxyd of gold is precipitated of a purple colour; and, when scraped off and collected, forms the purple powder of Cassius, much employed

---

* The nitro-muriate of gold, employed in these experiments, should be previously evaporated to dryness, in order to expel the superfluous acid, and afterward dissolved in distilled water.

in enamelling. The same precipitate is obtained by mixing a solution of gold with a solution of tin in muriatic acid.

9. Gold is precipitated from its solvent by ether, but the oxyd of gold is instantly redissolved by the ether, and forms the ethereal solution of gold.

10. Sulphurets of alcalis unite with gold both in the dry and humid way. To exhibit this, some leaf-gold may be digested, with heat, in a solution of sulphuret of potash.

ART. XX. — *Platina.*

1. Platina is a white metal, resembling silver in colour, but greatly exceeding it, and indeed all other metals, in specific gravity.

2. It is, of all metals, the most difficult of fusion. It may be melted, however, by a blow-pipe, with the aid of oxygenous gas.

3. It is not oxyded when exposed red-hot to the air for a considerable length of time.

4. It dissolves in no acid, except the nitro-muriatic and oxygenated muriatic acids.

5. These solutions are decomposed by alcalis, and also by a solution of muriate of ammonia, which last has no effect on solutions of gold.

ART. XXI. — *Silver.*

1. Silver, also, is a metal which is difficultly oxyded by the concurrence of heat and air.

2. It is acted on by sulphuric acid, which, when assisted by heat, oxydates and partly dissolves it.

3. Nitric acid dissolves it with a disengagement of nitrous gas, and the solution, when evaporated, shoots into regular crystals. If the silver be pure the solution is colourless, otherwise it has a green hue.

4. Muriatic acid does not act on silver. Yet this acid takes silver from others. Thus when muriatic acid is added to nitrate of silver, a white curdy precipitate falls down in great abundance. This precipitate is decomposed by light; for, when exposed to the direct rays of the sun, its colour becomes gradually darker. If fused by a gentle heat, it forms a semi-transparent mass of the consistence of horn, called luna cornea, or horn-silver.

5. A solution of nitrate of silver stains animal substances a deep black. Hence it has been applied to the staining of human hair; but, when thus employed, it should be very much diluted, and used with great caution, on account of its corrosive quality.

6. The solution of nitrate of silver, when evaporated, forms regular crystals. These crystals fuse when heated, and being poured, in this state, into moulds, form the common lunar caustic.

7. Nitrate of silver is decomposed by other metals. Thus the surface of a plate of copper, to which a little of the solution is applied, becomes plated over with silver. If a little mercury be poured into a bottle filled with this solution, and the bottle be left some time undisturbed, the silver is precipitated in a beautiful form, resembling the branches of a tree, which has been termed *Arbor Dianæ*. (See Nicholson's Chemistry, page 249.)

8. Precipitate nitrate of silver by lime water, and wash and dry the precipitate. Let this be afterward put into a vessel of liquid ammonia. It will then assume the form of a black powder, from which the fluid is to be decanted, and the black substance left to dry in the air. This is the celebrated compound termed *fulminating silver*, which detonates with the gentlest heat, and even with the slightest friction. When once prepared, no attempt must be made to enclose it in a bottle, and it must be left undisturbed in the vessel in which it was dried. Great caution is necessary in the preparation of this substance and in making experiments on it. It even explodes, when moist, on the gentlest friction.

2. Silver is acted on by sulphurets of alcalis and by sulphurated hydrogen gas. Both these substances blacken silver when exposed to their operation, and the common tarnishing of silver has been traced to a similar cause.

ART. XXII. — *Mercury.*

1. Mercury, or quicksilver, is the only one of the metals that retains a fluid form at the ordinary temperature of the atmosphere.

2. When its temperature is reduced to about 40° below zero of Faht, it assumes a solid form. This is a degree of cold, however, that only occurs in high northern latitudes: and in this country quicksilver can only be exhibited in a solid state by means of artificial mixtures. See page 105.

3. At about 600° of Faht, mercury boils and is changed into vapour. Hence it may be driven over

by distillation, and may thus be purified, though not accurately, from the admixture of other metals.

4. Mercury is not oxydated, when pure, at the ordinary temperature of the atmosphere, but when boiled for a considerable time in a glass vessel, with a long narrow neck, it is converted into a reddish brown oxyd.

5. Mercury is dissolved by hot sulphuric acid and forms a white salt. When this is washed with boiling water, a yellow substance is obtained called turbith mineral.

6. Mercury is dissolved by nitric acid, and nitrous gas is disengaged. The properties of the solution vary accordingly as it is made with or without heat, the mercury in the former case being more highly charged with oxygen. When the nitrate of mercury is evaporated to dryness and made very hot, it is changed into a bright red oxyd, which still contains a small portion of acid.

7. Mercury is the basis of a new fulminating compound lately discovered by Mr E. Howard. To prepare this powder, 100 grains (or a greater proportional quantity not exceeding 500) are to be dissolved, with heat, in a measured ounce and half of nitric acid. The solution being poured cold upon two measured ounces of alcohol, previously introduced into any convenient glass vessel, a moderate heat is to be applied till effervescence is excited. A white fume then begins to undulate on the surface of the liquor, and the powder will be gradually precipitated on the cessation of action and reaction. The precipitate is to be immediately collected on a filtre, well washed

with distilled water, and cautiously dried in a heat not exceeding that of a water-bath. The immediate washing of the powder is material, because it is liable to the reaction of the nitric acid; and while any of that acid adheres to it, it is very subject to the action of light. From 100 grains of mercury, about 120 or 130 of the powder are obtained. (See Phil. Trans, 1800, p. 214.) This powder has the property of detonating loudly in a gentle heat or by light friction.

The following curious fact, respecting the fulminating mercury, we owe to Mr Accum. Four ounces of this substance were placed, still wet, on a chalk-stone, and left in this situation, unobserved, for three months. The product was found converted into a brilliant black powder. On attempting to collect it into a heap, and to separate it from the paper which had been interposed, a globule of running mercury was seen. On introducing the powder into a bottle, and shaking it, heat was evolved, and the whole reduced to the metallic state. Nich. Journ. 8vo. i. 299.

8. Mercury is not dissolved by muriatic acid, but may be brought into union with this acid by double elective affinity. Thus when sulphate of mercury and muriate of soda, both well dried, are mixed and exposed to heat, we obtain a combination of oxyd of mercury and muriatic acid. This compound is the *corrosive sublimate* of the shops. The same components, with a still farther addition of mercury, constitute an insoluble substance called *calomel*.

In calomel the oxyd of mercury contains about 10 per cent. of oxygen, and the salt about 88 of the oxyd and 12 of muriatic acid. Corrosive sublimate, in 100 parts, has 82 of an oxyd containing 15 per cent. of oxygen. (Chenevix. Phil. Trans, 1801.)

9. The oxyds of mercury are all reduced by heat alone, without the addition of any combustible substance, and afford oxygenous gas.

10. Mercury dissolves gold, silver, tin, and many other metals; and, if these be combined with it in sufficient quantity, the mercury loses its fluidity and forms an amalgam. A solid amalgam of lead and another of bismuth, on admixture together, have the singular property of instantly becoming fluid.

ART. XXIII. — *Iron.*

1. Iron is oxyded by the action of air, with the aid of an increased temperature, and gains about 28 per cent. The oxyd, thus obtained, is black.

2. It is oxyded also by water, both at the ordinary temperature of the air and in a high temperature. Iron filings, moistened with water, acquire rust and become oxyded, and the vapour of water gives up its oxygen to red-hot iron, the hydrogen being liberated in an uncombined state, see p. 34.

3. Iron is attacked by most acids. The sulphuric acid, when concentrated, acts but feebly on iron without the assistance of heat. But when diluted the iron is first oxyded by the decomposition of the water, and this oxyd is dissolved by the acid. The solution, when evaporated, gives the *sulphate of iron*, which has the following properties:

A. It forms regular-shaped crystals, of a green colour, which have an astringent taste and dissolve readily in water.

B. From this combination an oxyd of iron is thrown down by alcalis and by earths, varying in colour with the kind and state of the precipitant.

C. When the iron, contained in this salt, is still farther oxyded, the colour of the salt changes to red; and, if the oxydation be carried still farther, the iron becomes insoluble in sulphuric acid, affording an example of a metal soluble only when oxyded to a certain degree. Mere exposure to air is sufficient to precipitate an oxyd of iron, and the effect is rapidly produced by adding a little oxygenated muriate of potash to a solution of the salt.

The different states of oxydation of iron, when combined with sulphuric and other acids, have been discovered, by M. Proust, to be the foundation of essential differences in the characters of these salts. According to this ingenious chemist, there exist two varieties of sulphate of iron, the green and the red. In the green sulphate, the iron contains 27 per cent. of oxygen, in the red, 48. The green salt, when pure, is soluble in alcohol; its solution is of a pale green colour, it is not altered by the gallic acid, and gives a white precipitate with prussiate of potash. The red sulphate is soluble in alcohol, and uncrystallizable, it forms a black precipitate with the gallic acid and a blue one with prussiates. The green sulphate may be changed into the red by long exposure to the air, by oxygenated muriatic acid, or by nitric acid. The red sulphate may be changed into the green one by agitation in contact with sulphated hydrogen gas. The common sulphate of iron is a mixture of these two in various proportions. (See Ann. de Chimie, vol. 23.)

D. The sulphate of iron is decomposed by heat alone. When distilled in an earthen retort, the sulphuric acid passes over and an oxyd of iron remains in the retort.

4. Iron is acted on by the muriatic and nitric acids, and by the last, when concentrated, very violently, so that the acid undergoes a complete decomposition. The compounds thus obtained do not admit of being crystallized, and, like the sulphate of iron, exist in two different states, the green and the red, which vary according to the degree of oxydation of the iron. (Davy, 186).

5. Iron may be united, in the way of double elective affinity, with the prussic acid *. Thus, when prussiate of potash and sulphate of iron, both in solution, are mixed together, the prussic acid and oxyd of iron quit their former combinations and unite together. The beautiful blue precipitate is prussiate of iron.

A. Prussiate of iron is nearly insoluble in water.

B. It is not soluble in acids.

C. It is decomposed by a red heat, the prussic acid being destroyed and an oxyd of iron remaining.

D. It is decomposed by pure alcalis and earths, which abstract the prussic acid and leave an oxyd of iron. Thus, when pure potash is digested with prussiate of iron, its beautiful blue colour disappears, and we obtain a compound of potash and prussic acid, or a prussiate of potash.

---

* This acid will be mentioned hereafter.

In Nicholson's Journal (4to. iv. 30. 171.) I have given an improved process for preparing the prussiate of potash. The following, after trying various modes of preparation, I find to afford the purest test.

(a) To a solution of potash, deprived of its carbonic acid by quicklime, and heated nearly to the boiling point, in an iron kettle, add, by degrees, powdered Prussian blue till its colour ceases to be discharged. Filter the liquor and wash the sediment with water till it ceases to extract any thing; let the washings be all mixed together and placed in an earthen dish in a sand-heat. When the solution has become hot, add a little dilute sulphuric acid, and continue the heat for about an hour. A copious precipitate will be formed of Prussian blue. Let this be separated by filtration, and assay a small quantity of the filtered liquor in a wine glass, with a little dilute sulphuric acid. If an abundant production of Prussian blue should still take place, fresh sulphuric acid must be added to the whole liquor, which must again, with this addition, be exposed to heat. These filtrations and additions of sulphuric acid must be repeated as long as any considerable quantity of prussian blue is produced, but when this ceases the liquor may finally be passed through a filtre.

(b) Prepare a solution of sulphate of copper in about four or six times its weight of warm water, and into the solution (a) pour this, as long as a reddish brown or copper-coloured sediment continues to appear. Wash this sediment, which is a prussiate of copper, with repeated affusions of warm water, and, when these come off colourless, lay the precipitate on a linen filter to drain, after which it may be dried on a chalk-stone.

(c) Powder the precipitate, when dry, and add it by degrees to a solution of pure potash, prepared as described, p. 43. The prussic acid will leave the oxyd of copper and pass to the alcali, forming a prussiate of potash as free from iron as it can be obtained.

(d) But, as the salt still contains sulphate of potash, a portion of this may be separated by gentle evaporation, the sulphate crystallizing first. To the liquor remaining add a solution of barytes in warm water (p. 112) as long as a white precipitate ensues, observing not to add more after its cessation. The solution of prussiate is now free, in a great measure, from iron, and entirely from sulphates; and, by gentle evaporation, will form, on cooling, beautiful crystals. A solution of these in cold water affords the purest prussiate of potash that can be prepared.

For the vegetable alcali either soda or ammonia may be substituted in the above process, if they be preferred.

E. When the prussiate of potash is mixed with sulphate of iron, in which the metal is as little oxyded as possible, the prussiate of iron that is formed is of a white colour, but gradually becomes blue, as the iron, by exposure to air, acquires more oxygen. (See Proust's Memoir, in Nicholson's Journal.)

F. The effect of a sympathetic ink may be obtained by writing with a pen dipped in a very dilute solution of prussiate of potash. No characters will appear till the paper is moistened with sulphate of iron, when letters of a Prussian blue colour will be apparent. The experiment may be reversed, by writing with sulphate of iron and rendering the characters legible by prussiate of potash.

6. When sulphate of iron is mixed with an infusion of galls, we obtain a black solution, which is a new combination of oxyd of iron, with the gallic acid and tan. The gallate and tannate of iron are, therefore, essential constituents of inks, the other ingredients of which are chiefly added with the view of keeping these suspended.

In order that the iron may unite with the gallic acid and tan, it must be combined with the sulphuric acid in the state of red oxyd, for the less oxydated iron, in the green salt, does not form a black compound with these substances. Iron filings, however, dissolve in an infusion of galls with an extrication of hydrogen gas; but the compound is not black till after exposure to air, which oxydates the iron still farther. This solution, with a sufficient quantity of gum, forms an excellent ink.

On the same principle may be explained the effect of metallic iron in destroying the colour of ink. When ink is digested with iron filings, and frequently shaken, its colour decays; and it also becomes colourless after having a stream of sulphuretted hydrogen gas passed through it. In both these cases the oxyd of iron is partly deoxydated. Characters written with ink, after this treatment, are at first illegible, but become black as the iron acquires oxygen from the air.

A. Write upon paper with an infusion of galls. The characters will not be legible till a solution of sulphate of iron is applied. This experiment may be reversed like the preceding one, No. 5, F.

B. The combination of iron, forming ink, is destroyed by pure and carbonated alcalis. Apply a solution of alcali to characters written with common ink. The blackness will disappear and the characters will become brown, an oxyd of iron only remaining on the paper.

Alcalis, added cautiously to liquid ink, precipitate the black combination, but an excess redissolves the precipitate.

C. Characters which have been thus defaced may again be rendered legible by an infusion of galls.

D. Ink is decomposed by most acids, which separate the oxyd of iron from the gallic acid in consequence of a stronger affinity. Hence ink-stains are removed by dilute muriatic acid and by some vegetable acids. Hence, also, if to a saturated solution of sulphate of iron there be added an excess of acid, the precipitate no longer appears on adding infusion of galls.

When a mixture of ink is heated with nitric acid, the yellow oxalate of iron is formed, and is precipitated on adding pure ammonia.

E. Ink is decomposed by age, partly in consequence of the farther oxydation of the iron, and partly, perhaps, in consequence of the decay, or escape, of the acid of galls. Hence ink-stains degenerate into iron-moulds, and these last are immediately produced on an inked spot of linen when washed with soap, because the alcali of the soap abstracts the gallic acid and leaves only an oxyd of iron.

F. Ink is decomposed by oxygenated muriatic acid, which destroys the gallic acid, and the resulting muriatic acid dissolves the oxyd of iron.

As all writing inks, into the composition of which iron enters, are liable to decay by time, and to be destroyed by various agents, an ink has been proposed by Mr Close, the basis of which is similar to that of printing ink. Take oil of lavender 200 grains, gum copal in powder 25 grains, and lamp-black from 2½ to 3 grains. With the aid of a gentle heat dissolve the copal in the oil of lavender, in a small vial, and then mix the lamp-black with the solution, on a marble slab or other smooth surface. After a repose of some hours the ink must be shaken before use, or stirred with an iron wire, and, if too thick, must be diluted with a little oil of lavender. (See Nicholson's Journal, 8vo. ii. 145.)

7. Iron is dissolved by water impregnated with carbonic acid. A few iron filings, when added to a bottle of aërated water, and occasionally shaken up, impregnate the water with this metal. The solution is decomposed by boiling, and in a less degree by exposure to air.

8. Iron combines with sulphur. (A) A paste of iron filings, sulphur, and water, if in sufficient quantity, will burst into flame. (B) A mixture of one part of iron filings and three parts of sulphur, accurately mixed, and melted in a glass tube, at the moment of union exhibit a brilliant combustion. (C) This sulphuret of iron, when moistened, rapidly decomposes

oxygenous gas. (D) When diluted sulphuric or muriatic acid is poured on it, we obtain sulphurated hydrogen gas.

Art. XXIV.— *Copper.*

1. Copper is oxydated by air. This may be shown by heating one end of a polished bar of copper, which will exhibit various shades of colour, according to the force of the heat.

2. Copper does not decompose water, even with the assistance of heat.

3. It combines with strong sulphuric acid, in a boiling heat, and affords a blue salt called sulphate of copper. (A) Sulphate of copper is a regularly crystallized salt, easily dissolved by water. (B) The solution is decomposed by pure and carbonated alcalis. The former, however, redissolve the precipitate. Thus, on adding pure liquid ammonia to a solution of sulphate of copper, a precipitate appears, which, on a farther addition of the alcali, is redissolved and affords a beautiful bright blue solution. (C) The sulphate of copper is decomposed by iron. In a solution of this salt immerse a polished plate of iron. The iron will soon acquire a covering of copper in a metallic state.

4. Copper dissolves readily in nitric acid, with a disengagement of nitrous gas. The salt resulting from this combination has the singular property of detonating with tin. See page 6, B.

5. Copper is soluble in muriatic acid, with the aid of heat.

6. When corroded by vinegar it forms verdigrise.

7. Copper combines with sulphur. A mixture of three parts of copper filings and one part of sulphur, when melted in a glass tube, exhibits a combustion more brilliant than that of iron and sulphur.

ART. XXV.—*Lead.*

1. Lead, when melted and exposed to the action of the air, becomes covered with a pellicle of oxyd. By long-continued exposure to heat it is converted into oxyds of different colours. This oxydation it is difficult to exhibit on a small scale. The oxyds of lead may, therefore, be examined as they are found in the shops, in the states of minium, or red lead; massicot; and litharge.

2. The oxyds of lead give up their oxygen on the application of heat. When distilled in an earthen retort, they afford oxygenous gas; and still more readily when distilled with the sulphuric acid.

3. Of all the acids the nitric acts most strongly on lead, nitrous gas being disengaged during the solution.

4. The muriatic and sulphuric acids decompose nitrate of lead, and form a difficultly-soluble muriate and sulphate.

5. The oxyds of lead decompose mûriate of soda. Mix two parts of finely-powdered red lead with one of common salt, and form the whole into a paste with water, adding more, occasionally, as the mixtûre becomes dry. The alcali will be disengaged, and the muriatic acid will unite with the oxyd of lead. Wash off the alcali, dry the white mass, and fuse it in a crucible. It will form the pigment called mineral or patent yellow.

6. Lead, when exposed to the vapour of vinegar, is slowly corroded into a white oxyd, or rather carbonate. This, when dissolved in distilled vinegar and crystallized, forms acetite of lead, or sugar of lead. This acetite of lead, and indeed all the soluble salts of lead, are decomposed by sulphurated hydrogen gas. Hence characters, written with acetite of lead, become legible on exposure to sulphurated hydrogen gas.

ART. XXVI. — *Tin.*

The properties of tin must be examined in the state of block tin; what is commonly known by the name of tin being nothing more than iron plates with a thin covering of this metal.

1. Tin melts on the application of a moderate heat; by a long continuance of which it is converted into a grey powder. This powder, when mixed with pure glass, forms a white enamel.

2. Tin is not oxyded by exposure to air with the concurrence of moisture, a property which is the foundation of its use in covering iron.

3. Tin is dissolved by all the three mineral acids.

4. Tin may be brought to combine with the oxygenated muriatic acid by first forming it into amalgam with mercury, triturating this with an equal weight of oxygenated muriate of mercury, and distilling the mixture. The result is a liquid which emits dense white fumes, when exposed to the air, and was formerly termed the fuming liquor of Libavius.

5. Solutions of tin have the property of precipitating the colouring matter of vegetables, a property which will be noticed hereafter.

ART. XXVII. — *Zinc.*

1. Zinc is melted by a very gentle heat.

2. It is rapidly oxyded by atmospherical air. When thrown into a red hot crucible it burns with a bright light, and a white oxyd sublimes.

3. It dissolves readily in all the mineral acids. With diluted sulphuric acid it affords the purest hydrogen gas that can be obtained. The salt, when evaporated, shoots into regular crystals, called sulphate of zinc.

4. It detonates, when mixed with powdered nitre, and projected into a red hot crucible.

ART. XXVIII. — *Bismuth.*

1. The proper solvent for bismuth is the nitric acid.

2. From this solution a white oxyd is precipitated by the mere addition of water. This oxyd, even when well washed, still contains a portion of acid. It forms the pigment called flake white.

3. This oxyd of bismuth is blackened by sulphurated hydrogen gas.

4. Bismuth forms a component of the fusible mixture of metals discovered by Sir Isaac Newton. Melt together in a crucible eight parts of bismuth, five of lead, and three of tin; or three of bismuth, one of lead, and five of tin. The result is a compound which will be found to melt in a heat less than that of boiling water, and which will even fuse under the surface of hot water.

ART. XXIX.—*Arsenic.*

1. Arsenic, as it is to be found in the shops, occurs in the state of a white oxyd, from which the metal may be obtained by the following process. Mix two parts of the white oxyd with one part of black flux *, and put them into a crucible. Invert, over this, another crucible, lute the two together with a little clay and sand, and apply a red heat to the lower one. The arsenic will be reduced, and will be found lining the inside of the upper crucible, in a form of metallic brilliancy.

2. Arsenic is oxyded by mere exposure to the air. It soon becomes tarnished, and loses its metallic lustre.

3. It is volatile. When laid on a heated iron, it evaporates in the form of a white smoke, and emits a strong smell of garlic.

4. It is acted on by all acids.

5. It gives a white stain to copper. Let a little of the metallic arsenic be put between two small plates of copper; bind these closely together, by iron wire, and heat them in a fire. The inside of the copper plates will be stained white by the arsenic.

6. The white oxyd of arsenic is soluble in water, which dissolves about $\frac{1}{80}$ of its weight.

7. The oxyd is soluble in most acids.

8. The oxyd of arsenic, by repeated distillation with nitric acid to dryness, is converted into an acid

---

* Black flux is formed by detonating, in a crucible, one part of nitre with two of cream of tartar.

termed *arsenic acid*, or acid of arsenic: and also by oxygenated muriatic acid.

9. The oxyd of arsenic, when mixed with powdered nitre, and detonated in a red hot crucible, affords a salt consisting of arsenic acid and potash, and termed *arseniate of potash*.

10. Oxyd of arsenic combines with fixed alcalis, both in the dry and humid ways.

11. It is decomposed, when distilled with sulphur, sulphureous acid being disengaged, and a bright red compound of arsenic and sulphur remaining, termed *realgar*. When water, saturated with sulphurated hydrogen gass, is added to the solution of arsenic, No. 6, a yellow precipitate is produced.

12. A beautiful green colour, termed, from its inventor, Scheele's green, is obtained by adding a solution of oxyd of arsenic in alcali to a solution of sulphate of copper. (See Scheele's Chemical Essays.)

Art. XXX. — *Antimony*.

1. Antimony, as it is found in the shops, is a compound of the metal with sulphur. From this, the metal may be obtained by first roasting off the sulphur, and then fusing the oxyd with black flux.

2. Metallic antimony is of a silvery white colour, very brittle, and of a plated or scaly texture.

3. Antimony is easily fused; and, when the fire is strongly urged, the antimony, if in a close vessel, may be volatilized.

4. It is oxyded by the concurrent action of heat and air.

5. Antimony is soluble in all acids. When the regulus is pulverized and distilled with twice its weight of oxygenated muriate of mercury, a compound comes over, into the receiver, of oxygenated muriatic acid and antimony, formerly termed, from its thick consistence, butter of antimony. From this, a white oxyd of antimony is precipitated by the mere affusion of water, which was formerly called Algaroth's powder. This powder, by solution in the acidulous tartrite of potash, affords a tartar emetic of certain efficacy.

6. If the crude sulphuret of antimony be boiled with solution of pure potash, the solution, on cooling, deposits a substance formerly termed Kermes mineral.

ART. XXXI.—*Manganese.*

1. Manganese never occurs in a metallic state; the black substance, known by that name, being a compound of manganese, with a large proportion of oxygen. The metal is obtained by mixing this oxyd, finely powdered, with pitch, making it into a ball, and putting this into a crucible, with powdered charcoal, $\frac{1}{10}$ of an inch thick on the sides, and $\frac{1}{4}$ of an inch deep at the bottom. The empty space is then to be filled with powdered charcoal, a cover is to be luted on, and the crucible exposed, for one hour, to the strongest heat that can be raised.

2. This metal is of a dusky white colour, and bright and shining in its fracture. When exposed to the air, it soon crumbles into a blackish brown powder, in consequence of its oxydation.

3. The metal is soluble in acids, but most readily in the nitrous. It is precipitated by alcalis in the form of a white powder.

4. The black oxyd of manganese gives up its oxygen when distilled alone in a retort, or still more readily and abundantly if distilled with a mixture of sulphuric acid.

5. It gives up its oxygen to muriatic acid. (See page 85.)

6. The black oxyd contains too much oxygen to dissolve in nitric acid; but when to a portion of this acid, in contact with the oxyd, a little sugar is added, and heat is applied, the oxyd is dissolved.

7. The black oxyd of manganese imparts to borate of soda, when melted with it, a violet colour. When this is effected by the blow-pipe, the colour may be destroyed by the interior flame, and again reproduced by the exterior one, or by a small particle of nitre. See Klaproth, p. 243, a.

8. When powdered manganese and nitre are mixed together, and thrown into a red hot crucible, the nitric acid is decomposed, and we obtain a compound of highly-oxydated manganese with potash. This compound has the singular property of exhibiting different colours, according to the quantity of water that is added to it. A small quantity gives a green solution, a farther addition changes it to a blue, more still to purple, and a still larger quantity to a beautiful deep purple. This phenomenon is well described in Klaproth, p. 240, a. Hence this has been termed the chameleon mineral. This property

is destroyed by a very small quantity of sulphuret of potash.

9. The rose-colour of solutions of manganese, in sulphuric and phosphoric acids, is destroyed by exposure to the light of the sun, and restored when removed into darkness. This effect depends on the deoxydation of the metal by the sun's rays.

ART. XXXII.—*Cobalt.*

1. Cobalt may be purchased, in a metallic form, at a price lower than that of pure silver, under the name of regulus of cobalt.

2. Cobalt becomes tarnished by exposure to air, but is not easily oxydated, to any extent, by the action of heat and air combined. Its property of influencing the magnet, Mr Chenevix suspects, is owing to a small admixture of iron.

3. Its best solvents are the nitric and nitro-muriatic acids; and the solutions have the singular property of forming sympathetic inks. Characters, written with these solutions, are illegible when cold; but, when a gentle heat is applied, they assume a beautiful blue or green colour*. This experiment is rendered more amusing, by drawing the trunk and branches of a tree in the ordinary manner, and tracing the leaves with a solution of cobalt. The tree appears leafless, till the paper is heated, when it suddenly becomes covered with beautiful foliage.

---

* For some ingenious speculations on the cause of these phenomena, consult Mr Hatchett's paper on the Carinthian molybdate of lead. Phil. Trans. 1796.

4. Oxid of cobalt is precipitated by carbonated alcalis from the nitric solution, at first of a peach-flower colour, and afterwards of a lilac hue.

5. Oxalic acid throws down, from solutions of cobalt, a rose-coloured precipitate.

6. Cobalt, when oxyded, forms zaffre, which has the property of giving a deep blue colour to glass. Cobalt is not acidifiable. (Darracq, in Nicholson's Journ. 8vo. i. 304.)

The rarer and newly discovered metals, molybdenite, uranite, tellurite, chrome, columbium, &c. I omit; because, owing to their dearness and scarcity, they are not likely to become subjects of experiment to the chemical student.

Art. XXXIII.—*Nickel.*

1. To obtain nickel in a state of purity, the metal usually sold under that name must be dissolved in diluted nitric acid; the solution, evaporated to dryness, and the dry mass must again, for three or four times, be alternately dissolved in the acid and boiled to dryness. After the last evaporation, the mass must be dissolved in a solution of pure ammonia, which has been proved, by its occasioning no precipitation from muriate of lime, to contain no carbonic acid. The solution is next to be evaporated to dryness; and, after being well mixed with twice or thrice its weight of black flux, is to be exposed to a violent heat in a crucible for half or three-quarters of an hour.

2. Nickel is not magnetic; for, when this property is exhibited by it, a contamination of iron is always

present. (Chenevix, in Nicholsons Journal, 4to. vol. v. p. 289.)

3. It is soluble in nitric, sulphuric, and muriatic, acids; and all its solutions have a beautiful green colour.

4. From the solutions, prussiate of potash throws down a sea-green precipitate.

5. Tincture of galls produces no change in these solutions.

6. The solution does not deposit its metal either on polished iron or zinc when immersed in it. (See Klaproth's Analytical Essays, p. 433.)

ART. XXXIV. — *Vegetable Substances.*

1. *Vegetable Extract.*

This may be obtained by evaporating the expressed juices of recent vegetables, or their infusions or decoctions. It has the following properties:

A. It is cohesive, of a brownish colour, and generally of a bitterish taste.

B. It is soluble in cold water, but much more readily in hot. Hence the decoctions of certain substances (Peruvian bark for example) become turbid on cooling.

C. It absorbs moisture from the atmosphere.

D. It is soluble in alcohol and in alcalis, but not in acids.

E. When to its solution in water oxygenated muriatic acid is added, a precipitate is thrown down, which is not soluble by the same agents as the original extract.

F. Extract is precipitated also by muriate of tin.

G. It is not precipitated by tan.

2. *Mucilage.*

This substance, in a dry state, is commonly known by the name of gum. Gum arabic may be employed as an example.

A. It is brittle, dry, and insipid.

B. It forms a viscid solution with water.

C. It is not dissolved by alcohol.

D. Its solution in water is precipitated by Goulard's extract of lead.

Beside this, there is another kind of mucilage termed viscid mucilage, found in etiolated and young plants, and in the sap of trees, of which it forms a considerable part. It may be obtained by boiling the marshmallow or quince-seeds in water. Its solution is more ropy than that of the gum mucilage, and it becomes sour by exposure to the air.

3. *Sugar and Oxalic Acid.*

1. Sugar is soluble in water, but less readily in alcohol.

2. Sugar, on the application of heat, swells and foams, and a black coal is left.

3. When heated with nitric acid, it is acidified. To six ounces of nitric acid, in a stoppered retort, to which a large receiver is luted, add, by degrees, one ounce of lump sugar coarsely powdered. A gentle heat may be applied during the solution. Nitrous gas will be disengaged in great abundance. When the whole of the sugar is dissolved, distil off a part of the acid. The remaining liquor will form

regular crystals, which must be again dissolved in water and crystallized. Lay this second crop of crystals on blotting paper to dry. They have the following properties.

A. They are readily soluble in water.

B. They have all the properties of an acid.

C. They are changed into a coal by a red heat.

D. They combine with alcalis and form neutral salts.

E. This acid has the property of forming an insoluble compound with lime. Into a glass of lime water let fall a drop or two of solution of acid of sugar. A white precipitate will immediately fall to the bottom of the vessel. The oxalic acid even separates lime from its combination with other acids. Hence a precipitation ensues on dropping oxalic acid into a solution of sulphate or muriate of lime.

4. *Native Vegetable Acids and Acidula.*

Native vegetable acids are such as are found, ready formed, in plants or their fruits, and require only pressure and other simple processes for their extraction.

A. *Citric Acid.* This exists, in an uncombined state, in the juice of lemons and of limes, or loosely combined with mucilage and extractive matter. It may be obtained, in a pure state, by saturating lemon juice with powdered chalk. A white precipitate will fall down, composed of citric acid and lime. To this, sulphuric acid, very much diluted, is to be added. The sulphuric acid will seize the lime and set the citric acid at liberty; and, when the solution is evaporated sufficiently low, the citric acid will shoot into regular crystals.

This acid is readily soluble in water, and may be applied to all the purposes for which fresh lemons are used.

B. *Gallic Acid.* This acid exists in the gall-nut, along with tan and other substances. It may be obtained by exposing an infusion of galls in water to the air. A mouldy pellicle will form on the surface of the infusion; and, after some months exposure, small yellow crystals will appear on the inside of the vessel. These crytals must be dissolved in alcohol, to separate them from other substances, and the solution evaporated to dryness.

It may also be obtained by sublimation. Pounded galls are to be put into a retort and heat applied. The gallic acid will rise and be condensed in the neck of the retort in a solid form. This process is recommended by Deyeux as preferable to any other.

The gallic acid requires 24 times its weight of cold water for solution, or three parts of boiling water. Alcohol, when cold, dissolves one fourth, or an equal weight, when heated. These solutions redden the infusion of litmus, and strike a deep black with solutions of iron *.

The gallic acid may also be separated from the infusion of galls by adding muriate of tin till the precipitate ceases to appear. This precipitate may be reserved for the experiments detailed under the article

* See the article *Iron.*

Tan. From the remaining solution the superabundant oxyd of tin must be precipitated by sulphuretted hydrogen gas, and the clear liquor, on evaporation, yields crystals of gallic acid.

From one ounce of galls, according to Haussman, about three drachms of gallic acid may be obtained.

In Nicholson's 8vo. Journal, vol. i. p. 236, a very simple process for obtaining gallic acid is proposed by M. Fiedler. Boil an ounce of powdered galls, in 16 ounces of water down to 8, and strain the decoction. Precipitate also 2 ounces of alum, dissolved in water, with a sufficient quantity of carbonate of potash, and, after having washed the precipitate extremely well, add it to the decoction, and digest the mixture for 24 hours, shaking frequently. The alumine combines with, and carries down, both the tan and extract; and the filtered solution yields, by gentle evaporation, crystals of gallic acid.

C. *Malic Acid.* This acid exists in the juice of apples, gooseberries, and of some other fruits, and is found mixed with the citric and occasionally with others. It may be obtained by evaporating the juice nearly to dryness, and then adding alcohol, which dissolves the acids and leaves the mucilage. To this solution of citric and malic acids in alcohol chalk is to be added to saturation, and the precipitate to be washed with boiling water, which takes up the malate of lime and leaves the citrate. The solution of the malate of lime may then be decomposed by sulphuric acid.

The malic acid cannot be crystallized, and, in general, forms deliquescent salts.

D. *Tartareous Acid and its Combinations.*

This acid may be obtained from common cream of tartar, by diſsolving it in boiling water, and adding chalk as long as any effervescence ensues. An insoluble tartrite of lime falls down, which may be decomposed, like the citrate of lime, by sulphuric acid. On evaporating the solution, regular crystals are obtained.

This acid is readily soluble in water. It combines with alcalis. When potash is exactly saturated with it a neutral salt is obtained, which dissolves very readily in water; but, on a still farther addition of acid, we obtain a salt which requires 20 parts of water for solution. This last is identical with common cream of tartar, which is a tartrite of potash, with a considerable excess of acid, and hence has been termed the acidulous tartrite of potash. By adding to this as much alcali as will saturate the excess of acid, it becomes easily soluble; and, by again rendering the acid superabundant, it is again rendered insoluble.

E. *Benzoic Acid.* This may be obtained from a substance termed gum benjamin, by sublimation. It exists in a solid form, and may be procured at the druggists' shops under the name of flowers of benjamin. These flowers have manifestly acid properties.

F. The oxalic acid is also found native in the juice of sorrel, forming a salt with excess of acid, or an acidulum.

5. *Fixed Oils.*

1. These oils are obtained, by pressure, from certain vegetables, as the olive, the almond, linseed, &c.

2. As thus obtained they are generally found combined with mucilage.

3. They do not combine with water or with alcohol.

4. They unite with alcalis and form soap.

5. Their properties are changed by boiling with metallic oxyds, those of lead for example. The mucilage unites with the oxyd, which probably gives up a portion of its oxygen to the oil, and the oil is rendered drying, and fit for the use of the painter.

6. *Volatile or Essential Oils.*

1. These oils have a penetrating smell and an acrid taste.

2. They are volatilized by a gentle heat.

3. They are soluble in alcohol.

4. They do not unite with water. With the intervention of a little sugar, however, they are combinable, in small proportion, with water.

5. When nitric acid is poured upon these oils, especially if it has been previously mixed with one fifth or one sixth of sulphuric acid, the mixture bursts out into a violent flame. This experiment requires caution, as the inflamed oil is apt to be scattered about.

6. Several of them detonate, when rubbed with oxygenated muriate of potash, and take fire when poured into oxygenated muriatic acid gas.

7. Essential oils are thickened by long exposure to air.

Camphor resembles the essential oils in many properties, but is not inflamed by nitric acid, which converts it into an acid distinguished by peculiar properties, and termed the camphoric acid.

7. *Resins.*

Resins are the inspissated juices of certain plants and are obtained, generally, by wounding their bark. Gum copal, or lac, may be taken as an example.

1. They are dry, brittle, and inflammable.

2. They dissolve readily in alcohol and essential oils, but not in water. From their solution in alcohol they are precipitated by water.

3. They are the basis of cements and varnishes, and are chiefly used in medicine.

Gum resins are resins mixed with extractive matter, and are soluble partly in alcohol and partly in water.

8. *Farina, or Fecula.*

Common starch may be taken as an example of farina. It will be found to have the following qualities:

1. It is not soluble in water, unless when heated to 160°; and if the temperature be raised to 180° the solution coagulates.

2. Like sugar, it is converted, by the action of the nitric acid, into oxalic acid.

3. When distilled alone, it yields an acid termed the pyromucous. This has been lately shown to be identical with vinegar.

4. Farina forms a considerable part of wheat and other flour, and of the potatoe. It may be obtained separate by washing with water.

5. It becomes sour when exposed in a moist state to the air.

9. *Gluten.*

1. Gluten may be obtained from wheat flour, by kneading it into dough with water, and washing off from this all the farina, by repeated affusions of water, working it at the same time with the fingers.

2. It is elastic, and, when drawn out, recovers itself something like the elastic gum. When strongly heated it shrinks, and, if distilled in a retort, unlike other vegetable substances, it yields ammonia.

3. When exposed moist to the atmosphere it does not turn sour, but putrefies like animal matter.

4. It is soluble in pure alcalis, and precipitable by acids.

10. *Elastic Gum, or Caoutchouc.*

1. This substance is inflammable.
2. It is insoluble in water.
3. It is imperfectly dissolved by spirit of turpentine.
4. Its only solvent is ether, and, when employed for this purpose, the ether should be previously washed.

This may be done by shaking it in a bottle half filled with water and half with ether. The bottle is next to be held inverted, and the water, which is the heaviest, suffered to escape. In this way about half the ether is lost, and the remainder is considerably stronger than before. This solution may be so applied as to form hollow tubes.

11. *The Woody Fibre.*

1. This forms the basis of all wood, and is more abundant in proportion as the wood is harder.

2. It is insoluble in water.

3. When exposed to heat it affords a peculiar acid called the pyroligneous, which has been lately proved identical with the acetous. In the retort a black substance remains, which is charcoal.

12. *Colouring Matter.*

The colouring matter exists in vegetables, combined with various other principles; and, according to the nature of the substance with which it is combined, it is soluble by different menstrua. It has an affinity for alumine and for oxyd of tin, in consequence of which these solutions precipitate infusions of the colouring principle in water.

1. To a decoction of madder in water add a solution of sulphate of alumine. The alumine will combine with the colouring matter, and will form a coloured precipitate, or lake.

2. To the same decoction add a little of the nitromuriate of tin. The oxyd of tin will detach the colouring matter, and will form an insoluble precipitate.

3. Similar experiments may be made on an infusion of cochineal, which, though an animal production, owes its colouring matter, remotely, to a vegetable.

4. On this principle, of its attraction for colouring matter, depends the use of alum in dying, its basis serving as an intermedium between the cloth and the colouring principle.

13. *Tan, or the Tanning Principle.*

Tan may be obtained by any of the following processes:

A. Into a strong infusion of nut-galls pour the muriate of tin, till the yellowish precipitate, which falls down abundantly, ceases to appear. Wash the precipitate with a small quantity of distilled water, and afterwards add a sufficient quantity of warm water for its solution. From this solution the oxyd of tin is precipitated by a stream of sulphuretted hydrogen gas; and the tannin, which remains dissolved, may be procured by evaporation.

B. Into a saturated infusion of galls pour a saturated solution of carbonate of potash. The yellowish white precipitate, after being washed with a small quantity of water, affords the tan.

C. Into a similar infusion pour sulphuric or muriatic acid. A precipitate will form, which must be redissolved in water, and the excess of sulphuric acid saturated by carbonate of potash. When a farther addition is made of the alcali, the tan falls down, and must be purified by washing with a small quantity of water.

It has been lately discovered that the terra japonica (which is to be met with, under this name, in the druggists' shops) consists almost entirely of tan.

Tan has the following properties :

1. When evaporated to dryness it forms a brown friable mass, which has much resemblance in its fracture to aloes, a sharp bitter taste, and is soluble in hot water, but still more readily in alcohol.

2. From this watery solution all acids precipitate tan.

3. The watery solution, poured into one of glue, (inspissated animal jelly,) converts it immediately into a coagulum, which has the elastic properties of the gluten of wheat.

4. Green sulphate of iron effects no change in the solution of tan, but the red sulphate occasions a dark bluish precipitate. This precipitate differs from gallate of iron in being decomposed by acids, the tan being thus separated. An excess of the red sulphate redissolves the precipitate, and affords a black or dark blue liquor. By union with tan the red sulphate is deoxydated, the salt becoming the green sulphate, and the oxygen passing to the tan. Tan may also be oxygenized by passing streams of oxygenized muriatic acid through its solution in water.

14. *Wax.*

1. Wax is readily fusible and inflammable.

2. Yellow wax is bleached by oxygenated muriatic acid.

3. Wax is soluble in alcalis.

Results of the Decomposition of Vegetables.

Vinous fermentation. — The phenomena and result of this process should be accurately examined; which may be done with the aid of an apparatus similar to that described in Lavoisier's Elements, part 3.

The properties of alcohol may be exhibited by those of the spirit of wine generally found in the shops. Or the spirit may be converted into alcohol by adding to it dry carbonate of potash, as long as this is rendered moist by the spirit, and afterwards distilling off the alcohol with a very gentle heat.

1. Alcohol is considerably lighter than water.

2. It unites chemically with water, and caloric is evolved during the combination. A contraction of bulk also ensues. Hence a pint of water and a pint of alcohol, after admixture and when perfectly cold, are found to occupy a less bulk than two pints.

3. It is inflammable. During its combustion carbonic acid is generated, with a quantity of water, exceeding in weight the original weight of the alcohol. An ingenious apparatus proving this is figured in Lavoisier's Elements, plate IX. fig. 5.

4. Alcohol is the best solvent of resins and essential oils.

5. By distillation with such acids as readily give up their oxygen alcohol is changed into ether. Thus equal parts of sulphuric acid and of alcohol, mixed together very cautiously, by adding small portions of acid repeatedly to the alcohol, give, on distillation,

the liquor termed ether. It may be formed also by means of the nitric or oxygenated muriatic acids.

Ether.

1. Ether is extremely light, its specific gravity being even considerably less than that of alcohol.

2. It is not miscible with water, and, when these two fluids are shaken together, the ether, on standing, always rises to the surface.

3. It is extremely volatile. A few drops evaporate, almost instantly, from the palm of the hand.

4. During its evaporation a considerable degree of cold is produced. This may be shown by moistening repeatedly the bulb of a thermometer with ether and exposing it to the air. See also Art. II. No. 12.

5. Ether, at the temperature of 104°, exists in the state of a gas. This may be shown by filling a jar with water of this temperature, and inverting it in a vessel of the same. Then introduce a little ether, by means of a small glass tube closed at one end. The ether will rise to the top of the jar, and, in its ascent, will be changed into gas.

6. Ether is changed into gas by diminishing the weight of the atmosphere. Into a glass tube, about six inches long and half an inch diameter, put a tea-spoonful of ether, and fill up the tube with water. Then, pressing the thumb on the open end of the tube, place it, inverted, in a jar of water. Let the whole be set under the receiver of an air-pump and the air exhausted. The ether will be changed into gas, which will expel the water entirely from the tube. On read-

mitting the air into the receiver, the gas is again condensed into a liquid form.

7. The gas produced by the volatilization of ether is inflammable. Fill a small and very strong phial with oxygen gas, and let fall into it a drop of ether. On contact with the flame of a candle a loud explosion will take place.

8. The following experiment, evincing the inflammability of ether, is described by Mr Cruickshank, in Nicholson's Journal, 4to. v. 205:

Fill a bottle, of the capacity of three or four pints, with the pure oxygenized muriatic acid gas, taking care to expel the water as completely as possible. Then throw into it about a drachm or a drachm and half of good ether, covering its mouth immediately with a piece of light wood or paper. In a few seconds white vapour will be seen moving circularly in the bottle, and this will soon be followed by an explosion, accompanied with flame. At the same time a considerable quantity of carbon will be deposited, and the bottle will be found to contain carbonic acid gas.

The same effect is produced, but more slowly, by alcohol; and, along with the carbonic acid and carbon, a little ether is produced.

Acetous Acid.

1. Common vinegar, purified by distillation, may be taken as an example of acetous acid.

2. The acetous acid may be concentrated by exposure to cold, which congeals the water sooner than the real acid, and affords a mean of separating it.

3. Acetous acid unites with alcalis, earths, and metallic oxyds.

A. When potash, saturated with this acid, is evaporated to dryness, the salt assumes a black colour. On being redissolved, however, and again evaporated, the salt is obtained white, and, when fused and suffered to cool, affords the acetite of potash.

This salt strongly attracts moisture from the air, and is very soluble in water. When exposed to a pretty strong heat, it is decomposed; carbonic acid and carbonated hydrogen gasses come over; and in the retort there remains a mixture of carbon with carbonate of potash.

When this salt is distilled, with half its weight of sulphuric acid, the vegetable acid is expelled in a very concentrated form, and is then termed

Acetic Acid.

1. This acid has a very strong taste and a most pungent smell.

2. It is very volatile, and is inflammable when heated, taking fire on the approach of a lighted paper and burning like alcohol.

3. It unites with alcalis, and the solutions, when evaporated, do not become black. Hence it is probable that the change of acetous into acetic acid depends in great measure on the separation of carbon.

4. This acid may be obtained from the acetite of copper by distillation per se.

5. The acetic acid, in the temperature of 38° of Fahr. congeals or becomes glacial, and again liquefies at 39°.

6. When distilled with alcohol, it affords an ether termed acetic ether.

The acetous acid may be also combined with oxyds of lead and of copper. Lead corroded into a white oxyd, or rather carbonate, by the fumes of vinegar, forms ceruse, or white-lead, which, when dissolved in distilled vinegar and crystallized, constitutes the acetite or sugar of lead. This salt is not decomposed without the addition of sulphuric acid. Copper, corroded in a similar manner, produces verdigris, which, when dissolved in distilled vinegar, affords a crystallizable salt, called acetate of copper. From this the acetic acid may be separated by distillation per se.

From late experiments by Darracq, it appears that acetic acid differs from the acetous only in containing less water and no mucilage. This chemist succeeded in converting the acetous into the acetic, merely by abstracting its water by muriate of lime, under circumstances where no farther oxygenation could take place.

ART. XXXV. — *Animal Substances.*

1. *Animal Jelly.*

Animal jelly may be extracted from most of the soft parts of animals, and even from bones, by long continued boiling. It forms the basis of soups, broth, &c. and imparts to these their nutritious properties.

It is readily soluble in warm water, and congeals, when cold, into a cohesive substance, which may again be dissolved by water. It becomes sour when exposed to the influence of the air. When evaporated to dryness, it forms portable soup, glue*, isinglass, &c.

Animal jelly is precipitated by a solution of tan, in the form of a coagulum, which, when dry, has a vitreous fracture, is not susceptible of putrefaction, is quite insoluble in water and in alcohol, and recovers its elasticity when moistened with warm water. This compound appears, from the experiments of Seguin, to be the preservative part of tanned leather, and that on which its most useful properties depend.

2. *Animal Albumen.*

The white of an egg may be employed in exhibiting the qualities of animal albumen.

A. Albumen is insoluble in water even at the boiling temperature.

B. It is soluble in pure alcalis, and is precipitated again by the addition of acids.

C. It is coagulated, by the temperature of 160°, into a solid cohesive mass; and also by acids, oxyds, and alcohol. The coagulum, thus produced, is soluble in alcalis only; and, during the solution, ammonia is evolved.

D. On exposure to air, it passes to the putrefactive state.

E. When exposed to a gentle heat, in a retort, with diluted nitric acid, azotic gas is disengaged,

---

* For an account of the preparation of glue, see Nicholson's Journal, 8vo. ii. 235.

which proceeds not from the acid, but from the animal matter.

F. Albumen is also precipitated by the solution of tan, but the precipitate is not characterized by similar elasticity.

Gluten, or Animal Fibre.

Gluten forms the basis of the muscular or fleshy parts of animals, and remains, combined with albumen, when all the soluble parts have been washed away by water. It may, also, be obtained from coagulated blood, by laying this on a linen strainer, and pouring on water till a white fibrous matter alone remains.

1. Gluten is insoluble in water, except by the long continued heat of a Papin's digester.

2. It is soluble in acids and in pure alcalis.

3. With diluted nitric acid, it yields much more azotic gas than any other animal substance.

4. It differs from albumen, in being coagulated by the mere contact of air, and by a temperature of 120°, and in being insoluble in cold liquid ammonia. Its structure also is fibrous, whereas that of albumen is smooth and homogeneous.

Animal Oil.

Animal oil differs from the vegetable oils in being generally solid at the temperature of the atmosphere, but is similar to them in its other properties. Among animal oils, may be ranked butter, tallow, lard, suet, spermaceti, &c. They all contain a peculiar acid, called the sebacic acid. This may be obtained, by adding to the oil, when liquified by heat, finely-powdered quicklime, collecting the sebate of lime and distilling it with sulphuric acid.

A singular instance, of the production of animal oil from the lean or muscular part of animals, is presented by the conversion of muscle into a substance strongly resembling spermaceti. To effect this conversion, it is only necessary to confine the fleshy part of an animal, in a box with several holes in it, under the surface of a running stream. When thus confined, the change takes place spontaneously in the course of a few months. But it may be accomplished much sooner by digesting animal muscle in strong nitric acid, and washing off the acid by water as soon as the change has ensued. The spermaceti, thus obtained, may be bleached by exposure to the oxygenated muriatic acid gas.

Animal Acids.

Of these I shall mention none except the prussic acid, as being the only one likely to be the subject of experiment.

The prussic acid is formed in animal matters when exposed to a high temperature. Let blood be evaporated to dryness, and let the dried blood be mixed with an equal weight of carbonate of potash, and the mixture be exposed to heat in a crucible, two thirds only of which are filled. The crucible is to have a cover applied, and the heat must be kept up till the flame ceases to proceed from the materials. By this operation, the prussic acid is formed and combines with the potash. The prussiate of potash is next to be washed off by repeated affusions of water, and mixed with a solution of sulphates of iron and alumine. The precipitate thus formed, when washed with muriatic acid, will assume a beautiful blue colour, which is owing to a combination of prussic acid with oxyd of iron. This prussiate of iron has the properties already described, page 126, No. 5.

The prussic acid may be obtained in a separate state by the following process:

Mix two ounces of red oxyd of mercury, prepared by nitric acid, with four ounces of finely-powdered Prussian blue, and boil the mixture with twelve ounces of water in a glass vessel, shaking frequently. Filter the solution, which is a prussiate of mercury, while hot; and, when cool, add to it in a bottle two ounces of iron filings, and six or seven drachms of sulphuric acid; shake these together, decant the clear liquor into a retort, and distill off one fourth of the liquor.

The distilled liquor is the prussic acid, which has a peculiar smell, a sweet taste, and does not like other acids redden vegetable blue colours, but combines with alcalis and earths.

PART II.

Directions for examining Mineral Waters and Mineral Bodies in general.

THE complete and accurate analysis of mineral waters, and of mineral bodies in general, is one of the most difficult subjects of chemical manipulation, and requires a very extensive acquaintance with the properties and habitudes of a numerous class of substances. Long and attentive study of the science is therefore essential, to qualify any one for undertaking exact and minute determinations of the proportion of the component parts of bodies. Such minuteness, however, is scarcely ever required in the experiments that are subservient to the ordinary purposes of life; a general knowledge of the composition of bodies being sufficient to assist in directing the most useful applications of them. I shall not attempt, therefore, to lay down rules for accurate analysis, but shall only describe such experiments as are suited to afford an insight into the kind, but not to decide the exact proportion, of the constituent principles of natural waters and of mineral substances in general.

SECT. I.—*Examination of Mineral Waters.*

Water is never presented by nature in a state of complete purity. Even when collected as it descends in the form of rain, chemical tests detect in it a minute proportion of foreign ingredients. And, when it has been absorbed by the earth, has traversed its different strata, and is returned to us by springs, it is found to have acquired various impregnations. The readiest method of judging of the contents of natural waters, is by applying what are termed tests, or reagents; *i. e.* substances which, on being added to a water, exhibit, by the phenomena they produce, the nature of the saline or other ingredients. For example, if on adding infusion of litmus to any water, its colour is changed to red, we infer that the water contains an uncombined acid: if this change ensues, even after the water has been boiled, we judge that the acid is a fixed and not a volatile one: and if, on adding the muriated barytes, a precipitate falls down, we safely conclude that the peculiar acid, present in the water, is, either entirely or in part, the sulphuric acid. I shall first enumerate the tests generally employed in examining waters, and describe their application; and, afterwards, indicate by what particular tests the substances, generally found in waters, may be detected.

1. *Infusion of Litmus, Syrup of Violets, &c.*

As the infusion of litmus is apt to spoil by keeping, I include in the chest some solid litmus. The infusion is prepared by steeping this substance, first bruised in a mortar and tied up in a thin rag, in distilled water, which extracts its blue colour.

If the colour of the infusion tends too much to purple, it may be amended by a drop or two of solution of pure ammonia; but of this no more must be added than is barely sufficient, lest the delicacy of the test should be impaired.

The syrup of violets is not easily obtained pure. The genuine syrup may be distinguished from the spurious by a solution of corrosive sublimate, which changes the former to green, while it reddens the latter. When it can be procured genuine, it is an excellent test of acids, and may be employed in the same manner as the infusion of litmus.

Paper stained with the juice of the March violet, or with that of radishes, answers a similar purpose. In staining paper for the purposes of a test, it must be used unsized; or, if sized, it must previously be washed with warm water; because the alum, which enters into the composition of the size, will otherwise change the vegetable colour to red.

In the Philosophical Magazine, vol. i. p. 180, may be found some recipes for other test liquors invented by Mr Watt.

Infusion of litmus is a test of most uncombined acids.

(1) If the infusion redden the unboiled, but not the boiled, water, under examination, or, if the red colour, occasioned by adding the infusion to a recent water, return to blue, on boiling, we may infer that the acid is a volatile one, and most probably the carbonic acid. Sulphuretted hydrogen gas, dissolved in water, also reddens litmus, but not after boiling.

(2) To ascertain whether the change be produced by carbonic acid or sulphuretted hydrogen, when experiment shows that the reddening cause is vola-

tile, add a little lime water. This, if carbonic acid be present, will occasion a precipitate, which will dissolve, with effervescence, on adding a little muriatic acid. Sulphuretted hydrogen may also be contained in the same water, which will be ascertained by the tests hereafter to be described.

(3) Paper tinged with litmus is also reddened by the presence of carbonic acid, but regains its blue colour on drying. The mineral and fixed acids redden it permanently. That these acids, however, may produce their effect, it is necessary that they should be present in a sufficient proportion. (See Kirwan on Mineral Waters, p. 40.)

II. *Infusion of Litmus reddened by Vinegar,—Spirituous Tincture of Brazil wood,—Tincture of Turmeric, and Paper stained with each of these three Substances,—Syrup of Violets.*

All these different tests have one and the same object.

(1) Infusion of litmus reddened by vinegar, or litmus paper reddened by vinegar, has its blue colour restored by pure alcalis and pure earths, and by carbonated alcalis and earths.

(2) Turmeric paper and tincture are changed to a reddish brown by alcalis, whether pure or carbonated, and by pure earths, but not by carbonated earths.

(3) The red infusion of brazil wood, and paper stained with it, become blue by alcalis and earths, and even by the latter when dissolved by an excess

of carbonic acid. In the last-mentioned case, however, the change will either cease to appear, or be much less remarkable, when the water has been boiled.

(4) Syrup of violets, when pure, is, by the same causes, turned green*; as also paper stained with the juice of the violet or with radishes.

III. *Tincture of Galls.*

Tincture of galls is the test generally employed for discovering iron, with all the combinations of which it produces a black tinge, more or less intense according to the quantity of iron. The iron, however, in order to be detected by this test, must be in the state of red oxyd, or if oxydated in a less degree, its effect will not be apparent, unless after standing some time in contact with the air. By applying this test before and after evaporation or boiling, we may know whether the iron be held in solution by carbonic acid or a fixed acid; for,

(1) If it produce its effect before the application of heat, and not afterward, carbonic acid is the solvent.

(2) If after as well as before, a mineral acid is the solvent.

(3) If by the boiling a yellowish powder be precipitated, and yet galls continue to strike the water black afterwards, the iron, as often happens, is dissolved both by carbonic acid and by a fixed acid. A neat mode

---

* According to Mr Accum, syrup of violets which has lost its colour by keeping may be restored by agitation, during a few minutes, in contact with oxygen gas.

of applying the gall-test was used by M. Klaproth, in his analysis of the Carlsbad water: a slice of the gall-nut was suspended by a silken thread in a large bottle of the recent water, and so small was the quantity of iron, that it could only be discovered in water fresh from the spring. (Klaproth, p. 279.)

IV. *Sulphuric Acid.*

(1) Sulphuric acid discovers, by a slight effervescence, the presence of carbonic acid, whether uncombined or united with alcalis or earths.

(2) If lime be present, whether pure or uncombined, the addition of sulphuric acid occasions, after a few days, a white precipitate.

(3) Barytes is precipitated, instantly, in the form of a white powder.

(4) Nitrous and muriatic salts, on adding sulphuric acid and applying heat, are decomposed; and if a stopper, moistened with solution of pure ammonia, be held over the vessel, white clouds will appear. For distinguishing whether nitric or muriatic acid be the cause of this appearance, rules will be given hereafter.

V. *Nitric and Nitrous Acids.*

These acids, if they occasion effervescence, give the same indications as the sulphuric. The nitrous acid has been recommended, as a test distinguishing between hepatic waters that contain sulphuret of potash, and those that contain only sulphuretted hydrogen gas. In the former case a precipitate ensues on adding nitrous acid, and a very fœtid smell arises; in the latter a slight cloudiness only appears, and the smell of the water becomes less disagreeable.

6. *Oxalic Acid and Oxalates.*

This acid is a most delicate test of lime, which it separates from all its combinations.

(1) If a water, which is precipitated by oxalic acid, become milky on adding a watery solution of carbonic acid, or by blowing air through it from the lungs by means of a quill or glass tube, we may infer that pure lime (or barytes, which has never yet been found pure in waters) is present.

(2) If the oxalic acid occasion a precipitate before but not after boiling, the lime is dissolved by an excess of carbonic acid;

(3) If after boiling, by a fixed acid. A considerable excess of any of the mineral acids, however, prevents the oxalic acid from occasioning a precipitate, even though lime be present; because some acids decompose the oxalic, and others, dissolving the oxalate of lime, prevent it from appearing. (Vid. Kirwan on Waters, page 88.)

The oxalate of ammonia or of potash (which may easily be formed by saturating their respective carbonates with a solution of oxalic acid) are not liable to the above objection, and are preferable, as reagents, to the uncombined acid. Yet even these oxalates fail to detect lime when supersaturated with muriatic or nitric acids; and, if such an excess be present, it must be saturated, before adding the test, with pure ammonia.

The fluate of ammonia, recommended by Scheele, I find to be a most delicate test of lime. It may be prepared by adding carbonate of ammonia to diluted fluoric acid, in a leaden vessel, observing that there be a small excess of acid.

7. *Pure Alcalis and carbonated Alcalis.*

(1) The pure fixed alcalis precipitate all earths and metals, whether dissolved by volatile or fixed menstrua, but only in certain states of dilution; for example, sulphate of alumine may be present in water, in the proportion of 4 grs to 500, without being discovered by pure fixed alcalis. As the alcalis precipitate so many substances, it is evident that they cannot afford any very precise information when employed as reagents. From the colour of the precipitate, as it approaches to a pure white or recedes from it, an experienced eye will judge that the precipitated earth contains less or more of metallic admixture.

(2) Pure fixed alcalis also decompose all salts with basis of ammonia, which becomes evident by its smell, and also by the white fumes it exhibits when a stopper, moistened with muriatic acid, is brought near.

(3) Carbonates of potash and soda have similar effects.

(4) Pure ammonia precipitates all earthy and metallic salts. Beside this property it also imparts a deep blue colour to any liquid that contains copper in a state of solution.

(5) Carbonate of ammonia has the same properties, except that it does not precipitate magnesia from its

combinations. Hence, to ascertain whether this earth be present in any solution, add the carbonate of ammonia till no farther precipitation ensues; filter the liquor, and then add pure ammonia. If any precipitation now occurs, we may infer the presence of magnesia.

8. *Lime-Water.*

As any quantity of lime-water that can be included in a chemical chest would very soon be expended, it will be necessary for the experimenter to prepare it himself, which may be done according to the process described in page 99.

(1) Lime-water is applied to the purposes of a test, chiefly for detecting carbonic acid. Let any liquor supposed to contain this acid be mixed with an equal bulk of lime-water. If carbonic acid be present, either free or combined, a precipitate will immediately appear, which, on adding a few drops of muriatic acid, will again be dissolved with effervescence.

(2) Lime-water will also show the presence of corrosive sublimate by a brick-dust-coloured sediment. If arsenic be contained in a liquid, lime-water, when added, will occasion a precipitate, consisting of lime and arsenic, which is very difficultly soluble in water. This precipitate, when mixed up with oil and laid on hot coals, yields the well-known garlic smell of arsenic.

9. *Pure Barytes and its solution in Water.*

(1) A solution of pure barytes is even more effectual than lime-water in detecting the presence of carbonic

acid, and is much more portable and convenient; since, from the crystals of this earth, which are also included in the chest, the barytic solution may at any time be immediately prepared. In discovering fixed air, the solution of barytes is used similarly to lime-water, and, if this acid be present, gives, in like manner, a precipitate soluble with effervescence in dilute muriatic acid.

(2) The barytic solution is also a most sensible test of sulphuric acid and its combinations, which it indicates by a precipitate not soluble in muriatic acid. — Pure strontites has similar virtues as a test.

10. *Metals.*

(1) Of the metals, silver and mercury are tests of the presence of sulphurets and of sulphuretted hydrogen gas. If a little quicksilver be put into a bottle containing water impregnated with either of these substances, its surface soon acquires a black film, and, on shaking, a blackish powder separates from it. Silver is immediately tarnished by the same cause.

(2) The metals may be used also as tests of each other, on the principle of elective affinity. Thus, for example, a polished iron plate, immersed in a solution of sulphate of copper, soon acquires a coat of this metal; and the same in other similar examples.

11. *Sulphate of Iron.*

This is the only one of the sulphates, except that of silver, applicable to the purposes of a test. When used with this view, it is generally employed for ascertaining the presence of oxygenous gas, of which a natural water may contain a small quantity.

A water, suspected to contain this gas, may be mixed with a little recently-dissolved sulphate of iron and kept corked up. If an oxyd of iron be precipitated, in the course of a few days the water may be inferred to contain oxygenous gas.

12. *Sulphate, Nitrate, and Acetite, of Silver.*

These solutions are all, in some measure, applicable to the same purpose.

(1) They are peculiarly adapted to the discovery of muriatic acid and of muriates. For, the silver, quitting the nitric acid, combines with the muriatic, and forms a flaky precipitate which, at first, is white, but, on exposure to the sun's light, acquires a blueish colour. This precipitate Dr Black states to contain, in 1000 parts, as much muriatic acid as would form 425½ of crystallized muriate of soda, which estimate scarcely differs at all from that of Klaproth. A precipitation, however, may arise from other causes, which it may be proper to state.

(2) The solutions of silver in acids are precipitated by carbonated alcalis and earths. The agency of these may be prevented by previously adding a few drops of the same acid in which the silver is dissolved.

(3) The nitrate and acetite of silver are decomposed by the sulphuric and sulphureous acids; but this may be prevented by adding, previously, a few drops of nitrate or acetite of barytes, and, after allowing the precipitate to subside, the clear liquor may be decanted

and the solution of silver added. Should a precipitation now take place, the presence of muriatic acid, or some one of its combinations, may be suspected. To obviate uncertainty whether a precipitation be owing to sulphuric or muriatic acid, a solution of sulphate of silver may be employed, which is affected only by the latter acid.

(4) The solutions of silver are also precipitated by sulphuretted hydrogen and by sulphurets; but the precipitate is then reddish, or brown, or black; or it may be, at first, white, and afterwards become speedily brown or black. It is soluble in dilute nitrous acid, which is not the case if occasioned by muriatic o sulphuric acid.

(5) The solutions of silver are precipitated by extractive matters; but, in this case also, the precipitate is discoloured and is soluble in nitrous acid.

13. *Nitrate and Acetite of Lead.*

(1) Acetite of lead, the most eligible of these two tests, is precipitated by sulphuric and muriatic acids; but, as of both these we have much better indicators, I do not enlarge on its application to this purpose.

(2) The acetite is also a test of sulphuretted hydrogen and of sulphurets of alcalis, which occasion a black precipitate; and, if a paper, on which characters are traced with a solution of acetite of lead, be held over a portion of water containing sulphuretted hydrogen, they are soon rendered visible.

(3) The acetite of lead is employed in the discovery of uncombined boracic acid, a very rare ingredient of

waters. To ascertain whether this be present, some cautions are necessary. (a) The uncombined alcalis and earths (if any be suspected) must be saturated with acetic or acetous acid. (b) The sulphates must be decomposed by acetite or nitrate of barytes, and the muriates by acetite or nitrate of silver. The filtered liquor, if boracic acid be contained in it, will give a precipitate soluble in nitric acid of the specific gravity of 1.3.

14. *Nitrate of Mercury prepared with and without Heat.*

This solution, differently prepared, is sometimes employed as a test. But, since other tests answer the same purposes more effectually, I have not thought proper to include the nitrate of mercury in the chest. For the same reason also oxygenated muriate of mercury is omitted.

15. *Muriate, Nitrate, and Acetite, of Barytes.*

(1) These solutions are all most delicate tests of sulphuric acid and of its combinations, with which they give a white precipitate insoluble in dilute muriatic acid. They are decomposed, however, by carbonates of alcali; but the precipitate occasioned by these is soluble in dilute muriatic or nitric acid, with effervescence, and may even be prevented by adding, previously, a few drops of the acid contained in the barytic salt.

One hundred grains of dry sulphate of barytes contain (according to Klaproth, p. 168) about 45½ of sulphuric acid of the specific gravity 1850; according to Clayfield, (Nicholson's Journal, 4to. iii. 38,) 33 of acid of s. g. 2240; according to Theraud, after calcination, about 25. These estimates differ very considerably.

From Klaproth's experiments it appears, that 1000 grains of sulphate of barytes indicate 595 of desiccated sulphate of soda, or 1416 of the crystallized salt. The same chemist has shown that 100 grains of sulphate of barytes are produced by the precipitation of 71 gr. of sulphate of lime.

(2) Phosphoric salts occasion a precipitate, also, which is soluble in muriatic acid without effervescence.

16. *Prussiates of Potash and of Lime.*

Of these two the prussiate of potash is the most eligible. When pure it does not speedily assume a blue colour on the addition of acid, nor does it *immediately* precipitate muriated barytes.

Prussiate of potash is a very sensible test of iron, with the solutions of which in acids it produces a Prussian blue precipitate, in consequence of a double elective affinity. To render its effect more certain, however, it may be proper to add, previously, to any water, suspected to contain iron, a little muriatic acid, with a view to the saturation of uncombined alcalis or earths, which, if present, prevent the detection of very minute quantities of iron.

(1) If a water, after boiling and filtration, does not afford a blue precipitate, on the addition of prussiate

of potash, the solvent of the iron may be inferred to be a volatile one, and probably the carbonic acid.

(2) Should the precipitation ensue in the boiled water the solvent is a fixed acid, the nature of which must be ascertained by other tests.

17. *Solution of Soap in Alcohol.*

This solution may be employed to ascertain the comparative hardness of waters. With distilled water it may be mixed, without any change ensuing; but if added to a hard water it produces a milkiness, more or less considerable as the water is less pure; and, from the degree of this milkiness, an experienced eye will derive a tolerable indication of the quality of the water. This effect is owing to the alcali quitting the oil, whenever there is present in a water any substance for which the alcali has a stronger affinity than it has for oil. Thus all uncombined acids, and all earthy and metallic salts, decompose soap, and occasion that property in waters which is termed hardness.

18. *Alcohol.*

Alcohol, when mixed with any water, in the proportion of about an equal bulk, precipitates all the salts which it is incapable of dissolving. (See Kirwan on Waters, p. 263.)

19. *Hydro-Sulphuret of Ammonia.*

This and other sulphurets, as well as water saturated with sulphuretted hydrogen, may be employed in detecting lead and arsenic, with the former of which they give a black, and with the latter a yellowish, precipitate. As lead and arsenic, however, are never found in natural waters, I shall reserve, for another occasion, what I have to say of the application of these tests.

Substances that may be expected in Mineral Waters, and the Means of detecting them.

Acids in general. Infusion of litmus. — Syrup of violets, I.

Acid, boracic. Acetite of lead, XIII. 3.

Acid, carbonic. Infusion of litmus, I. 1. 2. — Lime-water, VIII. 1. — Barytic water, IX. 1.

Acid, muriatic. Nitrate and acetite of silver, XII.

Acid, nitric. Sulphuric Acid, IV. 4.

Acid, phosphoric. Solutions of barytes, XV. 2.

Acid, sulphureous. By its smell, — and destroying the colour of litmus, and of infusion of red roses: — by the cessation of the smell a few hours after the addition of the black oxyd of manganese.

Acid, sulphuric. Solution of pure barytes, IX. Barytic salts, XV. Acetite of lead, XII.

Alcalis in general. Vegetable colours, II.

Ammonia, by its smell and tests, II.

Barytes and its compounds, by sulphuric acid, IV.

Carbonates in general. Effervesce on adding acids.

Earths dissolved by carbonic acid. By a precipitation on boiling; — by pure alcalis, VII.

Iron dissolved by carbonic acid. Tincture of galls, III. 1. Prussiate of potash, XVI. 1.

Iron dissolved by sulphuric acid. Same tests, III. 3. XVI. 2.

Lime in a pure state. Water saturated with carbonic acid. Blowing air from the lungs. Oxalic acid. VI.

—— *dissolved by carbonic acid.* Precipitation on boiling.—Caustic alcalis, VII. Oxalic acid, VI.

Magnesia dissolved by carbonic acid. Precipitation on boiling,—the precipitate soluble in dilute sulphuric acid.

Muriates of alcalis. Solutions of silver, XII.

——— *of lime.* Solutions of silver, XII. and oxalic acid, VI.

Sulphates in general. Barytic solutions, IX. and XV.—Acetite of lead, XII.

Sulphate of alumine. Barytic solutions, IX. and XV.—A precipitate by carbonate of ammonia not soluble in acetous acid, but soluble in pure fixed alcalis by boiling.

Sulphate of lime. Barytic solutions IX. and XV.—Oxalic acid, VI.—A precipitate by alcalis not soluble in dilute sulphuric acid.

Sulphurets of alcalis. Polished metals, X. Smell on adding sulphuric or muriatic acid.—Nitrous acid, V.

Sulphuretted hydrogen gas. Infusion of litmus, I. Polished metals, X. Acetite of lead, XIII, 2. *

---

* The vapour of putrefying organized matter dissolved in water, according to Klaproth, p. 590, often gives a deceptive indication of sulphuretted hydrogen.

The reader, who may wish for rules for the complete and accurate analysis of mineral waters, will find in almost every elementary work a chapter allotted to this subject. He may, also, consult Bergman's Physical and Chemical Essays, vol. i. Essay 2d, and Kirwan's Essay on the Analysis of Mineral Waters, London, 1799. As this manual, however, may sometimes be employed as a travelling companion, and may attend the chemist where more bulky works cannot be had, it may be proper to state, briefly, the mode of analyzing waters, by the more certain, but still not unobjectionable, mode of evaporation.

Before evaporation, however, the gaseous products of the water must be collected, which may be done by filling with it a large glass bottle capable of holding about 100 cubical inches, and furnished with a ground stopper and bent tube. The extricated gas must be received over mercury, into a graduated jar, by which its quantity will be ascertained.

The vessels, employed for evaporation, should be of such materials, as are not likely to be acted on by the contents of the water. I prefer those of unglased biscuit ware, made by Messrs Wedgewoods; but, as their surface is not perfectly smooth and the dry mass may adhere so strongly as not to be entirely scraped off, the water, when reduced to about one tenth or less, may be transferred, with any deposit that may have taken place, into a smaller vessel of glass. Here, let it be evaporated to dryness.

A. The dry mass, when collected and accurately weighed, is to be put into a bottle, and alcohol poured on it, to the depth of an inch. After having stood a few hours, and been occasionally shaken, pour the whole on a filter, wash it with a little more alcohol, and dry and weigh the remainder.

B. To the undissolved residue, add eight times its weight of cold distilled water; shake the mixture frequently; and, after some time, filter; ascertaining the loss of weight.

C. Boil the residuum, for a quarter of an hour, in somewhat more than 500 times its weight of water, and afterwards filter.

D. The residue, which must be dried and weighed, is no longer soluble in water or alcohol. If it has a brown colour, denoting the presence of iron, let it be moistened with water, and exposed to the sun's rays for some weeks.

I. The solution in alcohol (A) may contain one or all of the following salts:—muriates of lime, magnesia, or barytes, or nitrates of the same earths. Sometimes, also, the alcohol may take up a sulphate of iron, in which the metal is highly oxydated, as will appear from its reddish-brown colour.

1. In order to discover the quality and quantity of the ingredients, evaporate to dryness, add above half its weight of strong sulphuric acid, and apply a moderate heat. The muriatic or nitric acid will be expelled, and will be known by the colour of their fumes, the former being white, and the latter orange coloured.

2. To ascertain whether lime or magnesia be the basis, let the heat be continued till no more fumes arise, and let it then be raised, to expel the excess of sulphuric acid. To the dry mass, add twice its weight of distilled water. This will take up the sulphate of magnesia, and leave the sulphate of lime. The two sulphates may be separately decomposed by boiling with three or four times their weight of carbonate of potash. The carbonates of lime and magnesia, thus obtained, may be separately dissolved in muriatic acid and evaporated. The weight of the dry salts will inform us how much of each the alcohol had taken up.

The presence of barytes, which is very rarely to be expected, may be known by a precipitation ensuing on adding sulphuric acid to a portion of the alcohol-solution, which has been diluted with 50 or 60 times its bulk of pure water.

II. The watery solution (B) may contain a variety of salts, the accurate separation of which from each other is a problem of considerable difficulty.

1. The analysis of this solution may be attempted by crystallization. For this purpose, let one half be evaporated by a very gentle heat, not exceeding 80° or 90°. Should any crystals appear on the surface of the solution, while hot, in the form of a pellicle, let them be separated and dried on bibulous paper. These are muriate of soda or common salt. The remaining solution, on cooling very gradually, will, perhaps, afford crystals distinguishable by their form and other qualities. When various salts, however, are contained in the same solution, it is ex-

tremely difficult to obtain them sufficiently distinct to ascertain their kind.

2. The nature of the saline contents must, therefore, be examined by tests or reagents.

The presence of an uncombined alcali will be discovered by the stained papers, (p. 166,) and of acids by the tests, (p. 162). The vegetable alcali, or potash, may be distinguished from the mineral, or soda, by saturation with sulphuric acid, and evaporation to dryness; the sulphate of soda being much more soluble than that of potash; or by supersaturation with the tartarous acid, which gives a soluble salt with soda, but not with potash.

If neutral salts be present in the solution, we have to ascertain both the nature of the acid and of the basis. This may be done by attention to the rules already given for the application of tests, which it is unnecessary to repeat in this place.

III. The solution by boiling water contains scarcely any thing besides sulphate of lime.

IV. The residuum (D) is to be digested in distilled vinegar, which takes up magnesia and lime, but leaves, undissolved, alumine and highly-oxydated iron. Evaporate the solution to dryness. If it contain acetite of lime only, a substance will be obtained which does not attract moisture from the air; if magnesia be present, the mass will deliquiate. To separate the lime from the magnesia, proceed as in I.

The residue, insoluble in acetous acid, may contain alumine, iron, and silex. The two first may be dissolved by muriatic acid, from which the iron may be precipitated first by prussiate of potash, and the alumine afterward by a fixed alcali.

Sect. II. — *Examination of Minerals.*

The chemical analysis of minerals is attended even with greater difficulties than that of natural waters. It would, therefore, be a vain attempt to comprehend, in a concise manual, rules sufficiently minute for the accurate separation of their component principles. On the present occasion, I mean only to offer a few general directions for attaining such a knowledge of the composition of mineral bodies, as may enable the chemical student to refer them to their proper place in a mineral arrangement, and to judge whether or not they may admit of application to the uses of common life[*].

The great variety of mineral bodies, which nature presents in the composition of this globe, have been classed by late writers under a few general divisions. They may be arranged under four heads. 1st, Earths. 2dly, Salts. 3dly, Inflammable Fossils. — And, 4thly, Metals, and their Ores.

Earths. The formation of such a definition of earths as would apply exactly to the bodies defined, and to no others, is attended with considerable dif-

---

[*] Those who are solicitous to become adepts in the art of analysis, may read attentively the numerous papers on this subject dispersed through various chemical collections, and especially an admirable work of M. Klaproth, lately translated into English, entitled, Analytical Eſſays towards improving the chemical knowledge of Minerals. Published by Cadell and Davis, 1801.

ficulty, and indeed has never yet been effected. It would lead me into too long a discussion to comment, in this place, on the definitions that have been generally offered, and to state the grounds of objection to each of them. Sensible, therefore, that I am unable to present an unexceptionable character of earthy bodies, I shall select such a one as may be sufficient for the less accurate purpose of general distinction.

"The term earth," says Mr Kirwan, "denotes a tasteless, inodorous, dry, brittle, uninflammable, substance, whose specific gravity does not exceed 4. 9. (*i. e.* which is never five times heavier than water), and which gives no tinge to borax in fusion." After stating some exceptions to this definition, afforded by the strong taste of certain earths, and the solubility of others, he adds, "Since, however, a line must be drawn between salts and earths, I think it should begin where solution is scarcely perceptible; salts terminating, and earths, in strictness, commencing, where the weight of the water, requisite for the solution, exceeds that of the solvend 1000 times. But, not to depart too widely from the commonly received import* of words that are in constant use, substances, that require 100 times their weight of water to dissolve them, and have the other sensible properties of earths, may be so styled in a loose and popular sense."

The simple or primitive earths are those which cannot be resolved into more remote principles. Such are lime, argill, magnesia, &c.

The compound earths are composed of two or more primitive earths, united chemically together. Sometimes the union of an earth with an acid constitutes what is vulgarly called an earth, as in the examples of sulphate of lime, fluate of lime, &c.

Salts. Under this head Mr Kirwan arranges "all those substances that require less than 200 times their weight of water to dissolve them." This description, though by no means so amply characteristic of the class of salts as to serve for an exact definition, is sufficient for our present purpose.

"By *Inflammable Fossils*," the same author observes, "are to be understood all those of mineral origin, whose principal character is inflammability, a criterion which excludes the diamond and metallic substances, though also susceptible of combustion."

Metallic substances are so well characterized by external properties as not to require any definition. "Those on which nature has bestowed their proper metallic appearance, or which are alloyed only with other metals or semimetals, are called *native* metals. But those that are distinguished, as they commonly are in mines, by combination with some other unmetallic substances, are said to be mineralized. The substance that sets them in that state is called a mineralizer, and the compound of both an ore." Thus, in the most common ore of copper, this metal is found oxydated, and the oxyd combined with sulphur. The copper may be said to be mineralized by oxygen and sulphur, and the compound of the three bodies is called an ore of copper.

Method of examining a Mineral, the Composition of which is unknown.

A mineral substance, presented to our examination without any previous knowledge of its composition, should first be referred to one of the above four classes, in order that we may attain a general knowledge of its nature, before proceeding to analyze it minutely.

I. To ascertain whether the unknown mineral contain saline matter, let 100 grains, or any other determinate quantity, in the state of fine powder, be put into a bottle, and shaken up repeatedly with 30 times its weight of water, of the temperature of 120 or 130°. After having stood an hour or two, pour the contents of the bottle on a filtering-paper, previously weighed and placed on a funnel. When the water has drained off, dry the powder on the filter, in a heat of about 212°, and, when dry, let the whole be accurately weighed. If the weight be considerably less than the joint weight of the powder before digestion and the filtering-paper, we may infer that some salt has been dissolved, and the decrease of weight will indicate its quantity.

In certain cases it may be advisable to use repeated portions of boiling water, when the salt suspected to be present is difficult of solution.

Should the mineral under examination be proved, by the foregoing experiment, to contain much salt, the kind and proportion must next be determined, by rules which will hereafter be laid down.

II. The second class, viz. earthy bodies, are distinguished by their insolubility in water, by their freedom from taste, by their uninflammability, and by their specific gravity never reaching 5. If, therefore, a mineral be insoluble in water, when tried in the foregoing manner; if it be not consumed, either wholly or in considerable part, by keeping it, for some time, on a red hot iron; we may conclude that it is neither a salt nor an inflammable body.

III. The only remaining class with which it can be confounded are ores of metals, from many of which it may be distinguished merely by poising it in the hand, the ores of metals being always heavier than earths. Or, if a doubt should still remain, it may be weighed hydrostatically. The mode of doing this it may be proper to describe, but the principle on which the practice is founded cannot, with propriety, be explained here. Let the mineral be suspended by a piece of fine hair, silk, or thread, from the scale of a balance, and weighed in the air. Suppose it to weigh 250 grains. Let it next (still suspended to the balance) be immersed in a glass of water of the temperature of 60°. The scale containing the weight will now preponderate. Add, therefore, to the scale from which the mineral hangs as many grain weights as are necessary to restore the equilibrium. Suppose that 50 grains are necessary, then the specific gravity may be learned by dividing the weight in air by the weight lost in water. Thus, in the foregoing case, $250 \div 50 = 5$; or, a substance which should lose weight in water, according to the above proportion, would be five times heavier than water. It must, therefore, contain some metal, though probably in no great quantity. Any mineral, which, when weighed in the above manner, proves to be 5, 6, 7, or more, times heavier than water, may, therefore, be inferred to contain a metal, and may be referred to the class of ores.

IV. Inflammable substances are distinguished by their burning away, either entirely or in considerable part, on a red-hot iron; and by their detonating, when mixed with powdered nitre and thrown into a red hot crucible. Certain ores of metals, however, which contain a considerable proportion of inflammable matter, answer to this test, but may be distinguished from purely inflammable substances by their greater specific gravity.

I shall now proceed to offer a few general rules for the more accurate examination of substances of each of the above classes; without, however, pretending to comprehend, in this manual, a code of direction sufficiently minute to enable any one to perform a complete analysis.

1. *Examination of Salts.*

1. A solution of salt, obtained in the foregoing manner, (see page 187,) may be slowly evaporated and left to cool gradually. When cold, crystals will probably appear, which a chemist, acquainted with the form of salts, will easily recognize. But, as several different salts may be present in the same solution, and may not crystallize in a sufficiently distinct shape, it may be necessary to have recourse to the evidence of tests.

2. Let the salt, in the first place, be referred to one of the following orders:

(a) *Acids, or salts with excess of acid.* These are known by their effect on blue vegetable colours. The particular species of acid may be discovered by the tests described, page 178.

(b) *Alcalis.* These are characterized by their effect on vegetable colours, and by the other properties enumerated, page 43.

(c) *Salts with metallic bases.* These afford a very copious precipitate when mixed with a solution of prussiate of potash. To ascertain the species of metal, precipitate the whole by prussiate of potash, calcine the precipitate, and proceed according to the rules which will hereafter be given for separating metals from each other.

(d) *Salts with earthy bases.* If a solution of salt, in which prussiate of potash occasions no precipitation, afford a precipitate on adding pure or carbonated potash, we may infer that a compound of an acid, with some one of the earths, is present in the solution. Or if, after prussiate of potash has ceased to throw down a sediment, the above-mentioned alcali precipitates a farther portion, we may infer that both earthy and metallic salts are contained in the solution. In the first case, add the alcaline solution, and, when it has ceased to produce any effect, let the sediment subside, decant the supernatant liquor, and wash and dry the precipitate. The earths may be examined according to the rules that will be given in the following article. In the second case prussiate of potash must be added, as long as it precipitates any thing, and the liquor must be decanted from the sediment, which is to be washed with distilled water, adding the washings to what has been poured off. The decanted solution must next be mixed with the alcaline one, and the precipitated earths reserved for experiment. By this last process, earths and metals may be separated from each other.

E. *Neutral salts with alcaline bases.* These salts are not precipitated either by prussiate or carbonate of potash. It may happen, however, that salts of this class may be contained in a solution along with metallic or earthy ones. In this case the analysis becomes difficult, because the alcali, that is added to precipitate the two last, renders it difficult to ascertain whether the neutral salts are owing to this addition, or were originally present. I am not aware of any method of obviating this difficulty, except the following:—Let the metals be precipitated by prussiate of ammonia, and the earths by carbonate of ammonia, in a temperature of 180° or upwards, in order to ensure the decomposition of magnesian salts, which this carbonate does not effect in the cold. Separate the liquor by filtration and boil it to dryness. Then expose the dry mass to such a heat as is sufficient to expel the ammoniacal salts. Those with bases of fixed alcali will remain fixed. By this process, indeed, it will be impossible to ascertain whether ammoniacal salts were originally present; but this may be learned by adding to the salt under examination, before its solution in water, some pure potash, which, if ammonia be contained in the salt, will produce its peculiar smell. The vegetable and mineral alcalis may be distinguished by adding to the solution a little tartarous acid, which precipitates the former but not the latter.

Having ascertained the basis of the salt, the acid will easily be discriminated. Muriated barytes will indicate sulphuric acid; nitrate of silver the muriatic; and salts containing nitric acid may be known by a detonation ensuing on projecting them, mixed with powdered charcoal, into a red-hot crucible.

11. *Examination of Earths and Stones.*

When a mineral, the composition of which we are desirous to discover, resists the action of water, and possesses characters that rank it among earthy bodies, the next object of inquiry is the nature of the earths that enter into its composition; in other words, how many of the simple earths, and which of them, it may contain. Of these earths, viz. silex, alumine, magnesia, lime, strontites, and barytes, one or more, and sometimes all, may be expected in the composition of stones, beside a small proportion of metals, to which the colour of the stone is owing. In general, however, it is not usual to find more than four of the simple earths in one mineral. The newly-discovered earths, jargonia, glucine, &c. occur very rarely.

A stone which is intended for chemical examination should be finely powdered, and care should be taken that the mortar is of harder materials than the stone, otherwise it will be liable to abrasion, and uncertainty will be occasioned in the result of the process. A longer or shorter time is required, according to the texture of the stone. Of the harder gems, 100 grains require two or three hours trituration. For soft stones, a mortar of Wedgewood's ware is sufficient; but, for very hard ones, one of agate or hard steel is required; and the stone should be weighed both before and after pulverization, that the addition, if any, may be ascertained and allowed for. Gems, and stones of equal hardness, gain generally from 10 to 13 per cent. When a stone is extremely difficult to reduce to powder, it may sometimes be necessary to make it red hot, and, while in this state, to plunge it into cold water. By this process it becomes brittle, and is afterwards easily pulverized. But this treatment is not always effectual; for Klaproth found the hardness of corundum not at all diminished by igniting it, and quenching in cold water.

The chemical agents, employed in the analysis of stones, should be of the greatest possible purity. To obtain them in this state, directions have been given in the former part of this work.

In treating of the analysis of stones, it may be proper to divide them, 1st, into such as are soluble, either wholly or in part, and with effervescence, in nitric or muriatic acids, diluted with five or six parts of water; and, 2dly, into such as do not dissolve in these acids.

1. *Earths or stones, soluble with effervescence, in diluted nitric or sulphuric acids.**

A. If it be found, on trial, that the mineral under examination effervesces with either of these acids, let a given weight, finely powdered, be digested with one of them diluted in the above proportion,

---

* The sulphuric acid is chiefly eligible for stones of the magnesian genus.

in a gentle heat, for two or three hours. Ascertain the loss of weight, in the manner pointed out, page 187, and filter the solution, reserving the insoluble portion.

B. The solution, when effected, may contain lime, magnesia, alumine, barytes, or strontites. To ascertain the presence of the two last, dilute an aliquot part of the solution with 20 times its bulk of water, and add a little sulphuric acid, or, in preference, solution of sulphate of soda. Should a white precipitate fall down, we may infer the presence of barytes, of strontites, or of both.

C. To ascertain which of these earths, (viz. barytes or strontites,) is present, or, if both are contained in the solution, to separate them from each other, add sulphate of soda, till the precipitate ceases; decant the supernatant liquid; wash the sediment on a filter; and dry it. Then digest it, with four times its weight of pure carbonate of potash and a sufficient quantity of water, in a gentle heat, during two or three hours. A double exchange of principles will ensue, and we shall obtain a carbonate of barytes or strontites, or a mixture of both. Pour on these, nitric acid, of the specific gravity 1.4, diluted with an equal weight of distilled water. This will dissolve the strontites, but not the barytes. To determine whether any strontites has been taken up by the acid, evaporate the solution to dryness, and dissolve the dry mass in alcohol. This alcoholic solution, if it contain nitrate of strontites, will burn with a deep blood-red flame.

Barytes and strontites may, also, be separated from each other in the following manner. To a saturated solution of the two earths in an acid, add prussiate of potash, which, if pure, will occasion no immediate precipitation; but, after some time, small and insoluble crystals will form on the surface of the jar. These are the prussiated barytes, which may be changed into the carbonate by red heat, continued, with the access of air, till the black colour disappears. The strontites may be afterward separated from the solution by carbonate of potash.

A third method of separating strontites from barytes is founded on the stronger affinity of barytes, than of the former earth, for acids. Hence if the two earths be present in the same solution, add a solution of pure barytes, (see page 112.) till the precipitation ceases. The barytes will seize the acid, and will throw down the strontites. The strontitic solution, in this case, should have no excess of acid, which would prevent the action of the barytic earth*.

D. The solution (B,) after the addition of sulphate of soda, may contain lime, magnesia, alumine, and some metallic oxyds. To separate the oxyds, add prussiate of potash, till its effect ceases, and filter the solution, reserving the precipitate for future experiments.

---

* Klaproth separates barytes from ſtrontites by evaporating the ſolution of both in an acid. The barytic salt, being less soluble, separates first; and the strontic is contained in the last portions.

E. When lime, magnesia, and alumine, are contained in the same solution, proceed as follows:

(a) Precipitate the solution, previously made hot, by carbonate of potash; wash the precipitate well and dry it. It will consist of carbonates of lime, magnesia, and alumine. (b) The alumine may be separated, by digestion with a solution of pure potash, which will dissolve the alumine but not the other earths. (c) To this solution of alumine, add diluted muriatic acid, till the precipitate ceases; decant the supernatant liquor; wash the precipitate well with distilled water, and dry it. Then expose it to a low red heat, in a crucible, and weigh it, which will give the proportion of alumine.

F. Magnesia and lime may be separated by the following process. Evaporate the solution, in nitric or muriatic acid, to dryness. Weigh the dry mass, and pour on it, in a glass evaporating dish*, more than its own weight of strong sulphuric acid. Apply a sand heat, till the acid ceases to rise, and then raise the heat, so as to expel the excess of sulphuric acid. Weigh the dry mass, and digest it in twice its weight of cold distilled water. This will dissolve the sulphate of magnesia, and will leave the sulphate of lime, which must be put on a filter, washed with a little more water, and dried in a low red heat. To estimate the quantity of lime, deduct, from the weight of the sulphate, 59 per cent. Ac-

---

* The bottom of a broken Florence flask answers this purpose extremely well, and bears, without breaking, the heat necessary to expel the sulphuric acid.

cording to Klaproth, (p. 76, n.) crystallized sulphate of lime contains one third of earth.

If the lime be only in very small proportion to the magnesia, the two sulphates may be separated by evaporation, that of lime crystallizing first.

From Klaproth's experiments, 100 parts of sulphuric acid, spec. gr. 1850, when saturated with lime, give 160 of sulphate. To saturate 100 parts of this acid, 55 parts of pure lime are required, or 100 of carbonate of lime.

The magnesia is next to be precipitated from the sulphate by the carbonate of potash, in a heat approaching 212°; and the precipitate, after being well washed, must be dried, and calcined for an hour. Its weight, after calcination, will give the quantity of magnesia contained in the stone.

G. If magnesia and alumine only be contained in a solution, (the absence of lime being indicated by the nonappearance of a precipitate, on adding oxalate of ammonia,) the two earths may be separated by adding, to the cold solution, the carbonate of ammonia. This will separate the alumine, which may be collected, washed, and dried. To ascertain that a complete separation of the two earths has been accomplished, the process may be followed recommended by Klaproth, p. 418. The magnesia, remaining in solution, may be precipitated by carbonate of potash; heat being applied, to expel the excess of carbonic acid.

When the solution of magnesia, of alumine, or of both, contains a small proportion of iron, this may be separated from either or both of the earths by evaporating to dryness, calcining the residue, during two hours, in a low red heat, and dissolving again in dilute nitric acid, which does not take up iron when thus oxydated.

H. The insoluble residue (A) may contain alumine, silex, and oxyds of metals, so highly charged with oxygen as to resist the action of nitric and muriatic acids.

(a) Add concentrated sulphuric acid, and evaporate the mixture, to dryness, in the vessel described in the note p. 196. On the dry mass pour a fresh portion of the acid; boil again to dryness, and let this be done, repeatedly, three or four times. By this operation the alumine will be converted into a neutral sulphate of alumine, which will be rendered easily soluble in warm water, by adding a slight excess of acid*; and, if a portion of sulphate of potash be added, crystals of alum will form on evaporation. Let the sulphate of alumine be washed off, and the insoluble part be collected and dried. The alumine may be precipitated by carbonate of potash; washed, dried, and ignited; and its weight ascertained.

During the evaporation of a solution of alumine, which has been separated from silex, portions of the latter earth continue to fall, even to the last. (See Klaproth, p. 66 and 75.) These must be collected and washed with warm water, the collected earth added to the portion b, and the washings to the solution a.

---

* Mr Klaproth obtained crystals of alum from one fourth of a grain of alumine.

Alumine may be separated from oxyd of iron by a solution of pure potash.

From whatever acid alumine is precipitated by fixed alcali, it is apt to retain a small portion of the precipitant. To ascertain the true quantity of this earth, it must, therefore, be redissolved in acetous acid, again precipitated by solution of pure ammonia, dried, and ignited.

(b) The oxyds (generally of iron only) may be separated from the silex in the following manner: — Let the insoluble part (a) be heated in a crucible with a little wax. This will render the oxyds soluble in diluted sulphuric acid, and the silex will be left pure and white. Let it be washed, ignited, and its weight ascertained.

2. *Stones insoluble in diluted nitric and muriatic acids.*

These stones must be reduced to powder, observing the cautions given in page 192.

I. Let 100 grains, or any other determinate quantity, be mixed with three times their weight of pure and dry potash. Put the whole into a crucible of silver or platina, and add a little water *. The crucible, covered with a lid, must then be gradually heated; and, as the materials swell and would boil over, they are to be stirred constantly with a rod of silver

---

* Klaproth effected the disintegration of corundum (which resisted eleven successive fusions with alcali) by adding to the powdered stone, in a crucible, a solution of pure potash, boiling to dryness, and pushing the mixture to fusion. The alcali must be perfectly caustic, and must have been purified by alcohol, a recommended page 43.

or platina. When the moisture is dissipated, and the mass has become quite dry, raise the heat, as far as can be done without melting the crucible, if of silver, and continue the heat during half an hour or an hour.

The phenomena that occur during this operation indicate, in some degree, the nature of the mineral under examination. If the mixture undergo a perfectly liquid fusion, we may presume that the stone contains much siliceous earth; if it remain pasty and opaque, the other earths are to be suspected; and, lastly, if it have the form of a dry powder, the bulk of which has considerably increased, it is a sign of the predominance of alumine.

If the fused mass have a dark green or brownish colour, the presence of oxyd of iron is announced; a bright green indicates manganese, especially if the colour be imparted to water; and a yellowish green the oxyd of chrome.

K. The crucible, being removed from the fire, is to be well cleaned on the outside, and set, with its contents, in a porcelain or glass vessel, filled with hot water, which is to be stirred and renewed, occasionally, till the whole mass is detached. The water dissolves a considerable part of the compound of alumine and silex with potash, and even the whole, if added in sufficient quantity. During cooling, a sediment occasionally forms, in the filtered liquor, of a brownish colour, which is oxyd of manganese. (See Klaproth, 345, b.)

L. To the solution (K), and the mass that has resisted solution, in the same vessel, add muriatic acid. The first portions of acid will throw down a flocculent sediment, which consists of the earths that were held dissolved by the alcali. Then an effervescence ensues; and a precipitate occurs, which is no sooner formed than it is dissolved. Lastly, the portion that resisted the action of water is taken up, silently if it contains alumine, and with effervescence if it be calcareous earth.

M. From the phenomena attending the action of muriatic acid some indications may be derived. If the solution assume a purplish red colour, it is a sign of oxyd of manganese; an orange red shows iron; and a gold yellow colour betokens chrome. Freedom from colour proves that the stone contains no metallic ingredients.

N. When the solution is complete it is to be evaporated to dryness, in a glass vessel; but, if any thing resist solution, it must be heated, as before, (I,) with potash. When the liquor approaches to dryness, it assumes the form of a jelly, and must then be diligently stirred till quite dry.

O. (a) Let the dry mass be digested, in a gentle heat, with three or four pints, or even more, of distilled water, and filtered. (b) Wash what remains on the filter, repeatedly, till the washing ceases to precipitate the nitrate of silver, and add the washings to the filtered liquor. (c) Let the residue on the filter be dried and ignited in a crucible. Its weight shows the quantity of silex. If pure it should be perfectly white, but if it has any colour an admixture of some metallic oxyd is indicated. From this it may be purified by digestion in muriatic acid, and may again be washed, ignited, and weighed.

P. The solution (O), which, owing to the addition of the washings, will have considerable bulk, is next to be evaporated, till less than a pint remains; carbonate of potash must then be added, and the liquor must be heated during a few minutes. Let the precipitate, occasioned by the alcali, subside; decant the liquor from above it, and wash the sediment, repeatedly, with warm water. Let it then be put on a filter and dried.

Q. The dried powder may contain alumine, lime, magnesia, barytes, or strontites; besides metallic oxyds, which may be separated from each other by the rules already given.

R. It may be proper to examine the solution (P) after the addition of carbonate of potash, in order to discover whether any and what acid was contained in the stone.

(a) For this purpose let the excess of alcali be neutralized by muriatic acid and the liquor filtered.

(b) Add to a little of this liquor a solution of muriated barytes. Should a copious precipitate ensue, which is insoluble in dilute muriatic acid, the presence of sulphuric acid is detected. And if much barytes, strontites, or lime, has been found in the precipitate Q, we may infer the presence of a sulphate of one of these three earths.

(c) If, on mixing the liquid (a) with the solution of muriated barytes, a precipitate ensues which is soluble, without effervescence, in muriatic acid, the phosphoric acid may be known to be present; and, if lime be also found, the phosphate of lime is indicated.

(d) To a portion of the liquor (a) add a solution of muriate of lime till the precipitate, if any, ceases. Collect this precipitate, wash it, dry it, and pour on it a little sulphuric acid. Should acid fumes arise, the fluoric acid may be suspected. To ascertain its presence decisively, distil a portion of the precipitate with half its weight of sulphuric acid. The fluoric acid will be known by its effects on the retort, and by the properties described page 106.

8. The method of separating, from each other, the metallic oxyds, usually found as the colouring ingredients of stones, remains to be accomplished.

(a) Let the precipitate, by the prussiate of potash, (D,) be exposed to a red heat, by which the prussic acid will be decomposed. The oxyds thus obtained, if insoluble in dilute nitric or muriatic acid, will be rendered so by again calcining them with the addition of a little wax or oil.

(b) Or the process may be varied by omitting the precipitation by prussiate of potash, and proceeding as directed, E. page 196.

The oxyds will remain mixed with the magnesia and lime, and, after the addition of sulphuric acid, will be held in solution by that acid, along with magnesia only.

In both cases the same method of proceeding may be adopted, such variation only being necessary as is occasioned by the presence of magnesia in the latter.

(c) To the solution (a or b) containing several metallic oxyds dissolved by an acid, add a solution of crystallized carbonate of potash as long as any precipitation ensues. This will separate the oxyds of iron, chrome, and nickel; but the oxyd of manganese and the magnesia, if any be present, will remain dissolved.

If a small quantity of oxyd of manganese be suspected in an oxyd of iron, it may be detected by mixing the oxyd with nitre, and throwing the mixture into a red-hot crucible. Manganese will be indicated by an amethystine red tinge in the solution of this nitre.

(d) Magnesia and oxyd of manganese may be separated by adding to their solution (c) the hydro-sulphuret of potash, (see p. 71, F,) which will throw down the manganese, but not the magnesia. The precipitated manganese must be calcined with the access of air and weighed. The magnesia may afterward be separated by solution of pure potash; and, when precipitated, must be washed, dried, and calcined.

(e) The oxyd of chrome may be separated from those of iron and nickel, by repeatedly boiling the three, to dryness, with nitric acid. This will acidify the chrome, and will render it soluble in pure potash, which does not take up the other oxyds. From this combination with potash the chromic oxyd may be detached, by adding muriatic acid and evaporating the liquor till it assumes a green colour. Then, on adding a solution of pure potash, the oxyd of chrome will fall down, because the quantity of oxygen, required for its acidification, has been separated by the muriatic acid.

(f) The oxyds of iron and nickel are next to be dissolved in muriatic acid; and to the solution pure liquid ammonia is to be added, till there is an evident excess of it. The oxyd of iron will be precipitated, and must be dried and weighed. If highly oxydated, it must, before weighing, be calcined with wax, in a crucible. The oxyd of nickel remains dissolved by the excess of ammonia, to which it imparts a blue colour. It may be separated by evaporating the solution to dryness and dissolving the salt[*].

The analysis of the stone is now completed, and its accuracy may be judged by the correspondence of the weight of the component parts with that of the stone originally submitted to experiment.

It may be proper to observe, that certain stones, which are not soluble in diluted nitric and muriatic acids, may be decomposed by an easier process than that described A. Among these are the compounds of barytes, strontites, and lime, with acids, chiefly with the sulphuric, fluoric, and phosphoric. The sulphates of barytes, strontites, and lime; the fluate of lime; and the phosphate of lime; are all found native in the earth, and, except the last, are all insoluble in the above-mentioned acids. They may be known generally by their external characters. The compounds of barytes and strontites have a specific gravity greater than that of other earths, but inferior to that of metallic ores. They have, frequently, a regular or crystallized form, are more or less transparent, have some lustre, and their hardness is such as does not prevent their yielding to the knife. The combinations of lime, with the above-mentioned acids, are distinguished by simi-

---

[*] For an example of the separation of nickel from iron, see Klaproth, p. 422; where, also, and page 428, is an instance of the testing of nickel for copper.

lar characters, except that they are much less heavy. To the mineralogist the outward form and characters of these stones are sufficient indications of their composition.

Instead of the fusion with alcali, an easier process may be recommended. Let the mineral under examination be reduced to powder, and be digested, in nearly a boiling heat, during one or two hours, with three or four times its weight of carbonate of potash, and a sufficient quantity of distilled water. The acid, united with the earth, will quit it and pass to the potash, while the carbonic acid will leave the alcali and combine with the earth. We shall obtain, therefore, a compound of the acid of the stone with potash, which will remain in solution, while the carbonated earths will form an insoluble precipitate. The solution may be assayed to discover the nature of the acid, according to the formula I; and the earths may be separated from each other by the processes B, &c.

T. In the foregoing rules for analysis I have omitted the mode of detecting and separating *glucine*, because this earth is of very rare occurrence. When alumine and glucine are present in a mineral, they may be separated from the precipitate (E. a.) by pure potash, which dissolves both these earths. A sufficient quantity of acid is then to be added to saturate the alcali; and carbonate of ammonia is to be poured in till a considerable excess of this carbonate is manifested by the smell. The alumine is thus separated, but the glucine, being soluble in the carbonate of ammonia, remains dissolved, and may be precipitated by boiling the solution.

U. The presence of potash (which has lately been discovered in some stones) may be detected by boiling the powdered mineral, repeatedly, to dryness, with strong sulphuric acid. Wash the dry mass with water, add a little excess of acid, and evaporate the solution to a smaller bulk. If crystals of alum should appear, it is a decisive proof of potash, because this salt can never be obtained, in a crystallized form, without the addition of the vegetable alcali.

But, since a mineral may contain potash, and little or no alumine, in which case no crystals of alum will appear, it may be necessary, in the latter case, to add a little alumine along with the sulphuric acid. Or the stone may be so hard as to resist the action of sulphuric acid; and it will then be necessary to fuse it (in the manner directed, I) with soda, which has also a solvent power over alumine and silex. The fused mass is to be dissolved in water, and supersaturated with sulphuric acid. Evaporate to dryness, redissolve in water, and filter, to separate the silex. Evaporate the solution, which will first afford crystals of sulphate of soda and afterwards of sulphate of alumine, should this alcali be contained in the mineral.

Klaproth first discovered potash in leucite, on summing up the results of its analysis, which gave a considerable loss of weight. By boiling the stone with diluted muriatic acid, and evaporation, he obtained crystals of muriate of potash. Another proof of the presence of potash was, that, when sulphuric acid was boiled with it, the solution gave crystals of alum, to which potash is essential. He also boiled the stone with muriatic acid, and, after dissolving the muriate of alumine by alcohol, muriate of potash remained. The volcanic leucite contained less potash than other kinds. The same alcali he also detected, afterwards, in lepidolite.

The potash, contained in sulphate of alumine, may be separated from the earth by adding a solution of pure barytes as long as any precipitation is produced. The alumine and sulphate of barytes will fall down together, and the potash will remain in solution. Its presence may be known by the tests, p. 183, II. 2.

V. Soda may be detected in a mineral by the following experiments:—Let the powdered stone be treated with sulphuric acid, as in U; wash off the solution, and add pure ammonia till the precipitation ceases: then filter, evaporate the solution to dryness, and raise the heat so as to expel the sulphate of ammonia. The sulphate of soda will remain, and may be known by the characters, page 67.

Soda was first found, by Klaproth, in chryolite, in the large proportion of 36 per cent. This analysis was confirmed by Vauquelin, whose mode of separating it happens to be the one I now recommend.

2. *Substances which may be expected in Earths and Stones, and the Means of separating them from each other.*

Acid, fluoric, R. d.
 phosphoric, R. c.
 sulphuric, R. b.
Alumine from lime and magnesia, E.
 its quantity, E. c.
 from magnesia, G.

III. *Analysis of inflammable Fossils.*

The exact analysis of inflammable fossils is seldom necessary in directing the most beneficial application of them. It may be proper, however, to offer a few general rules for judging of their purity.

1. *Sulphur.* Sulphur should be entirely volatilized by distillation in a glass retort. If any thing remain fixed, it must be considered as an impurity and may be examined by the preceding rules.

Sulphur, also, should be totally dissolved by boiling with solution of pure potash, and may be separated from its impurities by this alcali.

Impure sulphur, consumed by burning in a small crucible, leaves a residue of oxyd of iron and silex.

2. *Coals.*

1. The proportion of bituminous matter in coal may be learnt by distillation, in an earthen retort, and collecting the product.

2. The proportion of earthy or metallic ingredients may be found, by burning the coal, with access of air, on a red-hot iron. What remains unconsumed must be considered as an impurity, and may be analyzed by the foregoing rules.

3. The proportion of carbon may be ascertained by observing the quantity of nitrate of potash which a given weight of the coal is capable of decomposing. For this purpose, let 500 grains, or more, of perfectly-pure nitre be melted in a crucible, and, when red-hot, let the coal to be examined, reduced to a coarse pow-

der, be projected on the nitre, by small portions at once, not exceeding one or two grains. Immediately, when the flame occasioned by one projection has ceased, let another be made, and so on till the effect ceases. The proportion of carbon in the coal is directly proportionate to the quantity required to alcalize the nitre. Thus, since 12·709 of carbon are required to alcalize 100 of nitre, it will be easy to deduce the quantity of carbon, in a given weight of coal, from the quantity of nitre which it is capable of decomposing. This method, however, is liable to several objections, which its inventor, Mr Kirwan, seems fully aware of. See his Elements of Mineralogy, vol. II. p. 514.

Plumbago, or *black lead*, is another inflammable substance which it may sometimes be highly useful to be able to identify, and to judge of its purity. — When projected on red-hot nitre, it should detonate; and, on dissolving the decomposed nitre, an oxyd of iron should remain, amounting to one tenth the weight of the plumbago. Any mineral, therefore, that answers to these characters, and leaves a shining trace on paper, like that of the black-lead pencils, is plumbago.

IV. *Analysis of Metallic Ores.*

The class of metals comprehends so great a number of individuals, that it is almost impossible to offer a comprehensive formula for the analysis of ores. Yet some general directions are absolutely necessary to enable the naturalist to judge of the composition of bodies of this class.

The ores of metals may be analyzed in two modes, in the humid and the dry way. The first is effected with the aid of acids and of other liquid agents, and may often be accomplished by persons who are prevented, by the want of furnaces and other necessary apparatus, from attempting the second.

It is hardly possible to employ a solvent capable of taking up all the metals. Thus, the nitric acid does not act on gold or platina; and the nitro-muriatic, which dissolves these metals, has no solvent action on silver. It will be necessary, therefore, to vary the solvent according to the nature of the ore under examination.

For ores of gold and platina, the nitro-muriatic acid is the most proper solvent. A given weight of the ore may be digested with this acid, as long as it extracts any thing. The solution may be evaporated to dryness, in order to expel the excess of acid, and dissolved in water. The addition of a solution of tin in muriatic acid will show the presence of gold by the purple precipitate; and platina will be indicated by a precipitate, on adding a solution of muriate of ammonia. When gold and platina are both contained in the same solution, they may be separated from each other by the last-mentioned solution, which throws down the platina but not the gold. In this way platina may be detached also from other metals.

When gold is contained in a solution along with several other metals, it may be separated from most of them by adding a dilute solution of sulphate of iron. The only metals, which this salt precipitates, are gold, silver, and mercury.

For extracting *silver* from its ores, the nitric acid is the most proper solvent. Nitric acid, however, does not act on horn-silver ore, which must be decomposed by carbonate of soda. The silver may be precipitated from nitric acid by muriate of soda (common salt). Every hundred parts of the precipitate contain 75 of silver. But, as lead may be present in the solution, and this metal is also precipitated by muriate of soda, it may be proper to immerse in the solution (which should not have any excess of acid) a polished plate of copper. This will precipitate the silver, if present, in a metallic form. The muriate of silver is also soluble in liquid ammonia, which that of lead is not. For examples of the analysis of silver ores, the reader may consult Klaproth, p. 554, &c.

Copper ores may be analyzed by boiling them with five times their weight of concentrated sulphuric acid, till a dry mass is obtained, from which water will extract the sulphate of copper. This salt is to be decomposed by a polished plate of iron, immersed in a dilute solution of it. The copper will be precipitated in a metallic state, and may be scraped off and weighed.

If silver be suspected along with copper, nitrous acid must be employed as the solvent, and a plate of polished copper will detect the silver.

The reader who engages in the analysis of copper ores will derive much advantage from the examples to be found in Klaproth's Essays, p. 54, 541, &c.; and also from Mr Chenevix's paper on the analysis of arseniates of copper and iron, Phil. Trans. 1801; Nicholson's Journal, 8vo. vol. i.; or Phil. Mag.

Iron ores may be dissolved in dilute muriatic acid, or, if too highly oxydated to be dissolved by this acid, they must be previously mixed with one eighth of their weight of powdered charcoal, and calcined in a crucible for one hour. The iron is thus rendered soluble.

The solution must then be diluted with 10 or 12 times its quantity of water, previously well boiled, to expel the air, and must be preserved in a well-stopped glass bottle for six or eight days. The phosphate of iron will, within that time, be precipitated, if any be present, and the liquor must be decanted off.

The solution may contain the oxyds of iron, manganese, and zinc. It may be pricipitated by carbonate of soda, which will separate them all. The oxyd of zinc will be taken up by a solution of pure ammonia; distilled vinegar will take up the manganese, and will leave the oxyd of iron. From the weight of this, after ignition, during a quarter of an hour, 28 per cent. may be deducted. The remainder shows the quantity of iron.

Tin ores. To that most accomplished analyst, Klaproth, we owe the discovery of a simple and effectual mode of analyzing tin ores in the humid way.

Boil 100 grains, in a silver vessel, with a solution of 600 grains of pure potash. Evaporate to dryness, and then ignite, moderately, for half an hour. Add boiling water, and, if any portion remain undissolved, let it undergo a similar treatment.

Saturate the alcaline solution with muriatic acid, which will throw down an oxyd of tin. Let this be redissolved by an excess of muriatic acid, again precipitated by carbonate of soda; and, being dried and weighed, let it, after lixiviation, be again dissolved in muriatic acid. The insoluble part consits of silex. Into the colourless solution, diluted with two or three parts of water, put a stick of zinc, round which the reduced tin will collect. Scrape off the deposit, wash, dry, and fuse it under a cover of tallow in a capsule placed on charcoal. A button of pure metallic tin will remain at the bottom, the weight of which, deducted from that of the ore, indicates the proportion of oxygen.

The presence of tin in an ore is indicated by a purple precipitate, on mixing its solution in muriatic acid with one of gold in nitro-muriatic acid.

Lead ores may be analyzed by solution in nitric acid diluted with an equal weight of water. The sulphur, if any, will remain undissolved. Let the solution be precipitated by carbonate of soda. If any silver be present, it will be taken up by pure liquid ammonia. Wash off the excess of ammonia by distilled water; and add concentrated sulphuric acid, applying heat, so that the muriatic acid may be wholly expelled. Weigh the sulphate of lead, and, after deducting 70 per cent. the remainder shows the quantity of lead.

Muriate of lead may also be separated from muriate of silver by its greater solubility in warm water. From the solution, iron may be separated by prussiate of potash, and the solution decomposed by sulphuric acid.

Mercury may be detected in ores that are supposed to contain it, by distillation in an earthen retort with half their weight of iron filings or lime. The mercury, if any be present, will rise and be condensed in the receiver.

Ores of zinc may be digested with the nitric acid, and the part that is dissolved boiled to dryness, again dissolved in the acid, and again evaporated. By this means the iron, if any be present, will be rendered insoluble in dilute nitric acid, which will take up the oxyd of zinc. To this solution add pure liquid ammonia, in excess, which will separate the lead and iron, if any should have been dissolved; and the excess of alcali will retain the oxyd of zinc. This may be separated by the addition of an acid.

Antimonial ores. Dissolve a given weight, in three or four parts of muriatic and one of nitric acid. This will take up the antimony, and leave the sulphur, if any. On dilution with water, the oxyd of antimony is precipitated, and the iron and mercury remain dissolved. Lead may be detected by sulphuric acid. See Klaproth on the analysis of antimoniated silver ore, p. 560.

Ores of arsenic may be digested with nitro-muriatic acid, composed of one part nitrous and one and a half or two of muriatic. Evaporate the solution to one fourth, and add water, which will precipitate the arsenic. The iron may afterwards be separated by ammonia. See Chenevix, Phil. Trans. 1801, p. 215.

Ores of bismuth are also assayed by digestion in nitric acid moderately diluted. The addition of water precipitates the oxyd, and, if not wholly separated at first, evaporate the solution; after which a farther addition of water will precipitate the remainder. See Analysis of an Ore of Bismuth and Silver, in Klaproth, p. 554. Mode of detecting a small Quantity of Silver in Bismuth, ditto, p. 220. c.

Ores of cobalt may be dissolved in nitro-muriatic acid. Then add carbonate of potash, which, at first, separates iron and arsenic. Filter, and add a farther quantity of the carbonate, when a greyish-red precipitate will fall down, which is oxyd of cobalt. The iron and arsenic may be separated by heat, which volatilizes the arsenic. Cobalt is also ascertained, if the solution of an ore in muriatic acid give a sympathetic ink: see p. 140. An example of the analysis of an ore of cobalt may be seen in Klaproth, p. 564; and of sulphate of cobalt, p. 579.

Ores of nickel. Dissolve them in nitric acid, and add to the solution pure ammonia, in such proportion that the alcali may be considerably in excess. This will precipitate other metals, and will retain the oxyd of nickel in solution, which may be obtained by evaporation to dryness, and heating the dry mass till the nitrate of ammonia has sublimed.

Ores of manganese. The earths, and several of the metals, contained in these ores, may first be separated by diluted nitric acid, which does not act on highly-oxydated manganese. The ore may afterward be digested with strong muriatic acid, which will take up the oxyd of manganese. Oxygenated muriatic acid will arise, if a gentle heat be applied, and may be known by its peculiar smell, and by its discharging the colour of wet litmus paper exposed to the fumes. From muriatic acid the manganese is precipitated by carbonate of soda, in the form of a white oxyd, which becomes black when heated in a crucible. Ores, suspected to contain manganese, may also be distilled per se, or with sulphuric acid, when oxygenous gas will be obtained. Oxyd of manganese may be separated from oxyd of iron by solution of pure potash, which takes up the former but not the latter. See the analysis of an ore of manganese, viâ humidâ, in Klaproth, p. 510; and of a cobaltic ore of manganese, p. 569.

Ores of manganese may also be distinguished by the colour they impart to borax, when exposed together to the blow-pipe. See p. 139.

Ores of uranite. These may be dissolved in dilute nitric acid, which takes up the uranitic oxyd and leaves that of iron; or in dilute sulphuric acid, which makes the same election. Or, if any iron has got into the solution, it may be precipitated by zinc. Then add caustic potash, which throws down the oxyds of zinc and uranium. The former may be separated by digestion in pure ammonia, which leaves, undissolved, the oxyd of uranite. This, when dissolved by dilute sulphuric acid, affords, on evaporation, crystals of a lemon-yellow colour.

If copper be present, it will be dissolved, along with the zinc, by the ammonia. If lead, it will form with sulphuric acid a salt much less soluble than the sulphate of uranite, and which, on evaporation, will, therefore, separate first.

Ores of tungsten. For these the most proper treatment seems to be digestion in nitro-muriatic acid, which takes up the earths and other metals. The tungsten remains in the form of a yellow oxyd, distinguishable, by its becoming white on the addition of liquid ammonia, from the oxyd of uranite. To reduce this oxyd to tungstenite, mix it with an equal weight of dried blood, heat the mixture to redness, press it into another crucible, which should be nearly full, and apply a violent heat for an hour at least.

Ores of molybdena. Repeated distillation to dryness, with nitric acid, converts the oxyd into an acid, which is insoluble in nitric acid, and may be thus separated from other metals, except iron, from which it may be dissolved by sulphuric or muriatic acids. The solution in sulphuric acid is blue when cold, but colourless when heated. That in muriatic acid is only blue when the acid is heated and concentrated. See Hatchett's Analysis of the Carinthian Molybdate of Lead, Phil. Trans. 1796; and Klaproth, p. 534, 538.

Analysis of Ores in the dry Way.

To analyze ores in the dry way, a method which affords the most satisfactory evidence of their composition, and should always precede the working of large and expensive strata, a more complicated apparatus is required. An assaying furnace, with muffles, crucibles, &c. are absolutely necessary; but, as these may be found described in most elementary books, I shall omit the detail of them in this place.

The reduction of an ore requires, frequently, previously roasting, to expel the sulphur and other volatile ingredients. Or this may be effected by mixing the powdered ore with nitre, and projecting the mixture into a crucible. The sulphate of potash, thus formed, may be washed off, and the oxyd must be reserved for subsequent experiments.

As many of the metals retain their oxygen so forcibly, that the application of heat is incapable of expelling it, the addition of inflammable matter becomes expedient. And, to enable the reduced particles of metal to agglutinate and form a collected mass, instead of scattered grains, which would otherwise happen, some fusible ingredient must be added, through which, when in fusion, the reduced metal may descend, and be collected at the bottom of the crucible. Substances that answer both these purposes are called *fluxes.* The alcaline and earthy part of fluxes serve also another end, viz. that of combining with any acid which may be attached to a metal, and which would prevent its reduction if not separated.

The ores of different metals, and different ores of the same metal, require different fluxes. To offer rules, however, for each individual case would occupy too much room in this work: I shall, therefore, only state a few of these fluxes that are most generally applicable.

The black flux (described page 136, note) is a very good one. Two parts of muriate of soda, previously dried in a crucible, one part of powdered lime, one part of fluate of lime, and half a part of charcoal: or, four hundred parts of calcined borax, forty of lime, and fifty of charcoal: or, two parts of pounded glass, one of borax, and half a part of charcoal, are all well adapted to the purpose of fluxes. The ore, after being roasted, if necessary, is to be well mixed with three or four times its weight of the flux and put into a crucible, with a little powdered charcoal over the surface. A cover must be luted on, and the crucible exposed to the necessary heat in a wind-furnace. Ores of iron, as being difficultly reduced, require a very intense fire. Those of silver and lead are metallized by a lower heat.

The volatile metals, as mercury, zinc, and arsenic, it is obvious, ought not to be treated in the above manner, and require to be distilled with inflammable matters in an earthen retort.

For minute instructions respecting the analysis of every species of ore, both in the humid and dry ways, I refer to the second volume of Mr Kirwan's Mineralogy.

PART III.

Application of chemical Tests and Reagents to various useful Purposes.

SECT. I. — *Method of detecting Poisons.*

WHEN sudden death is suspected to have been occasioned by the administration of poisons, either wilfully or by accident, the testimony of the physician is occasionally required, to confirm or invalidate this snspicion. He may also be sometimes called upon to ascertain the cause of the noxious effects, arising from the presence of poisonous substances in articles of diet; and it may, therefore, serve an important purpose, to point out concisely the simplest and most practicable modes of obtaining, by experiment, the necessary information.

The only poisons, however, that can be clearly and decisively detected by chemical means, are those of the mineral kingdom. Arsenic and corrosive sublimate are most likely to be exhibited with the view of producing death; and lead and copper may be introduced, undesignedly, in several ways, into our food and drink. The continued operation of the two last may often, unsuspected, produce effects less sudden and violent, but not less baneful to health and life, than the more active poisons; and their operation generally involves, in the pernicious consequences, a greater number of sufferers.

1. *Method of discovering Arsenic.*

When the cause of sudden death is believed, from the symptoms preceding it, to be the administration of arsenic, the contents of the stomach must be attentively examined. To effect this, let a ligature be made at each orifice, the stomach removed entirely from the body, and its whole contents washed out into an earthen or glass vessel. The arsenic, on account of its greater specific gravity, will settle to the bottom, and may be obtained separate by washing off the other substances, by repeated affusions of cold water. These washings should not be thrown away till the presence of arsenic has been clearly ascertained. It may be expected at the bottom of the vessel in the form of a white powder, which must be carefully collected, dried on a filter, and submitted to experiment.

A. Boil a small portion of the powder with a few ounces of distilled water, in a clean Florence flask, and filter the solution.

B. To this solution add a portion of water saturated with sulphuretted hydrogen gas (see page 70.) If arsenic be present, a golden-yellow sediment will fall down, which will appear sooner, if a few drops of acetic acid be added.

C. A similar effect is produced by the addition of sulphuret of ammonia.

D. To a little of the solution, A, add a single drop of a weak solution of carbonate of potash, and afterward a few drops of a solution of sulphate of copper. The presence of arsenic will be manifested by a yellowish-green precipitate.

E. The sediments, produced by any of the foregoing experiments, may be collected, dried, and laid on red-hot charcoal. A smell of sulphur will first arise, and will be followed by that of garlic.

F. But the most decisive mode of determining the presence of arsenic is by reducing it to a metallic state, in which its characters are clear and unequivocal. For this purpose, let a portion of the white sediment, collected from the contents of the stomach, be mixed with three times its weight of black flux, see page 136; or, if this cannot be procured, with two parts of dry carbonate of potash (the salt of tartar of the shops) and one of powdered charcoal. Procure a tube eight or nine inches long, and one sixth of an inch in diameter, of thin glass, sealed hermetically at one end. Coat the closed end with clay, for about an inch, and let the coating dry. Then put into the tube the mixture of the powder and its flux, and if any should adhere to the inner surface let it be wiped off by a feather, so that the inner surface of the upper part of the tube may be quite clean. Stop the end of the tube loosely, with a little paper, and heat the coated end only, on a chafing-dish of red-hot coals, taking care to avoid breathing the fumes. The arsenic, if present, will rise to the upper part of the tube, on the inner surface of which it will form a thin brilliant coating. Break the tube and scrape off the reduced metal. Lay a little on a heated iron, when, if it be arsenic, a dense smoke will arise, and a strong smell of garlic will be perceived. The arsenic may be farther identified by putting a small quantity between two polished plates of copper, surrounding it by powdered charcoal, to prevent its escape, binding these tightly together by iron wire, and exposing them to heat. If the included substance be arsenic a white stain will be left on the copper.

G. It may be proper to observe, that neither the stain on copper, nor the odour of garlic, is produced by the white oxyd, when heated without the addition of some inflammable ingredient. The absence of arsenic must not, therefore, be inferred, if no smell is occasioned by laying the white powder on a heated iron.

The late celebrated Dr Black ascertained, that all the necessary experiments, for the detection of arsenic, may be made on a single grain of the white oxyd; this small quantity having produced, when heated in a tube with its proper flux, as much of the metal as clearly established its presence.

If the quantity of arsenic in the stomach should be so small, which is not very probable, as to occasion death, and yet to remain suspended in the washings, the whole contents, and the water employed to wash them, must be filtered, and the clear liquor assayed for arsenic by the tests B, C, D, and E.

2. *Discovery of corrosive Sublimate.*

Corrosive sublimate, (the muriate of mercury,) next to arsenic, is the most virulent of the metallic poisons. It may be collected by treating the contents of the stomach in the manner already described; but, as it is more soluble than arsenic, viz. in about 19 times its weight of water, no more water must be employed than is barely sufficient, and the washings must be carefully preserved for examination.

If a powder should be collected, by this operation, which proves, on examination, not to be arsenic, it may be known to be corrosive sublimate by the following characters.

A. Expose a small quantity of it, without any admixture, to heat, in a coated glass tube, as directed in the treatment of arsenic. Corrosive sublimate will be ascertained by its rising to the top of the tube, lining the inner surface in the form of a shining white crust.

B. Dissolve another portion in distilled water; and it may be proper to observe how much of the salt the water is capable of taking up.

C. To the watery solution add a little lime-water. A precipitate of an orange-yellow colour will instantly appear.

D. To another portion of the solution add a single drop of a dilute solution of carbonate of potash (salt of tartar). A white precipitate will appear; but, on a still farther addition of alcali, an orange-coloured sediment will be formed.

E. The carbonate of soda has similar effects.

F. Sulphuretted water throws down a dark-coloured sediment, which, when dried and strongly heated, is wholly volatilized, without any odour of garlic.

The only mineral poison of great virulence that has not been mentioned, and which, from its being little known to act as such, it is very improbable we should meet with, is the carbonate of barytes. This, in the country where it is found, is employed as a poison for rats, and there can be no doubt would be equally destructive to human life. It may be discovered by dissolving it in muriatic acid, and by the insolubility of the precipitate which this solution yields on adding sulphuric acid (see page 114). Barytic salts, if these have been the means of poison, will be contained in the water employed to wash the contents of the stomach, and will be detected, on adding sulphuric acid, by a copious precipitate.

3. *Method of detecting Copper or Lead.*

Copper and lead sometimes gain admission into articles of food, in consequence of the employment of kitchen-utensils of these materials.

If copper be suspected in any liquor, its presence will be ascertained by adding a solution of pure ammonia, which will strike a beautiful blue colour. If the solution be very dilute it may be concentrated by evaporation; and, if the liquor contain a considerable excess of acid, like that used to preserve pickles, as much of the alcali must be added as is more than sufficient to saturate the acid.

Lead is occasionally found, in sufficient quantity to be injurious to health, in water that has been kept in leaden vessels, and sometimes even in pump-water, in consequence of this metal being used in the construction of the pump. Acetite of lead has, also, been known to be fraudulently added to bad wines, with the view of concealing their defects.

Lead may be discovered by adding, to a portion of the suspected water, about half its bulk of water impregnated with sulphuretted hydrogen gas. If lead be present it will be manifested by a dark brown or blackish tinge. This test is so delicate, that water, condensed by the leaden worm of a still-tub, is sensibly affected by it. It is, also, detected by a similar effect ensuing on the addition of sulphuret of ammonia or potash.

For discovering the presence of lead in wines, a test, invented by Dr Hahnemann, and known by the title of Hahnemann's wine-test, may be employed*. This test is prepared by putting together, into a small phial, sixteen grains of the sulphuret of lime, prepared in the dry way, (see page 100,) and 20 grains of acidulous tartrite of potash (cream of tartar). The phial is to be filled with water, well corked, and occasionally shaken for the space of ten minutes. When the powder has subsided, decant the clear liquor, and preserve it, in a well-stopped bottle, for use. The liquor, when fresh prepared, discovers lead by a dark-coloured precipitate. A farther proof of the presence of lead in wines is the occurrence of a precipitate on adding a solution of the sulphate of soda.

When a considerable quantity of acetite of lead has been taken into the stomach, (as sometimes, owing to its sweet taste, happens to children,) after the exhibition of an active emetic, the hydro-sulphuret of potash or of ammonia may be given; or a solution of the common sulphuret.

---

* See Phil. Mag. I. 31.

In cases of the accidental swallowing of sulphuric acid, which also sometimes happens to children, M. Fourcroy recommends the speedy administration of a solution of soap, or a mixture of carbonate of magnesia or carbonate of lime (common chalk) with water. (Systeme, vol. i, p. 240.)

SECT. II. — *Rules for ascertaining the Purity of chemical Preparations employed for the Purposes of Medicine and for other uses.*

1. *Sulphuric Acid,* — *Acidum Vitriolicum of the London Pharmacopœia.* — *Oil of Vitriol.*

The specific gravity of sulphuric acid should be 1850. It should remain perfectly transparent when diluted with distilled water. If a sediment should occur, on dilution, it is a proof of the presence of sulphate of lead or lime.

Iron will be detected in sulphuric acid by saturating a diluted portion of it with pure carbonate of soda, and adding prussiate of potash, which will manifest the presence of iron by a Prussian blue precipitate; or it will be discovered by a purplish or blackish tinge, on the addition of tincture of galls to a similarly-saturated portion. Copper may be discovered by pouring, into a similarly-saturated solution, pure solution of ammonia; and lead may be detected by the sulphuret of ammonia. The latter metal, however, is generally precipitated, on dilution, in combination with sulphuric acid.

Sulphate of potash or of soda may be found by saturating the diluted acid with ammonia, evaporating to dryness, and applying a pretty strong heat. The sulphate of ammonia will escape, and that of potash or of soda will remain, and may be distinguished by its solubility and other characters. (See page 67.)

2. *Nitric and nitrous Acids*, — *Acidum Nitrosum, Pharm. Lond.* — *Aqua fortis.*

The nitric acid should be perfectly colourless, and as limpid as water. It should be preserved in a dark place, to prevent its conversion into the nitrous kind.

These acids are most likely to be adulterated with sulphuric and muriatic acids. The sulphuric acid may be discovered by adding to a portion of the acid, largely diluted, nitrated or muriated barytes, which occasion, with sulphuric acid, a white and insoluble precipitate. The muriatic acid may be ascertained by nitrate of silver, which affords a sediment, at first white, but which becomes coloured by exposure to the direct light of the sun. Both these acids, however, may be present at once; and, in this case, it will be necessary to add a solution of nitrate of barytes, as long as any precipitate falls, which will separate the sulphuric acid. Let the sediment subside, decant the clear liquor, and add the nitrate of silver. If a precipitate appear, muriatic acid may be inferred to be present also. Muriatic acid may, also, be detected by adding a solution of sulphate of silver.

These acids should have the specific gravity of 1550.

3. *Muriatic Acid, — Acidum Muriaticum, P. L. — Spirit of Salt.*

This acid generally contains iron, which may be known by its yellow colour, the pure acid being perfectly colourless. It may also be detected by the same mode as was recommended in examining sulphuric acid.

Sulphuric acid is discoverable by a precipitation on adding, to a portion of the acid, diluted with five or six parts of pure water, a solution of the muriate of barytes.

The specific gravity of this acid should be 1170.

4. *Acetic Acid, — Acidum Acetosum, P. L. — Radical or concentrated Vinegar.*

This acid is often contaminated by sulphureous and sulphuric acid. The first may be known by drawing a little of the vapour into the lungs, when, if the acid be pure, no unpleasant sensation will be felt; but, if sulphureous acid be contained in the acetic, it will not fail to be discovered in this mode. The sulphuric acid is detected by muriated barytes; copper by supersaturation with pure ammonia; and lead by sulphuret of ammonia.

The specific gravity of this acid should be 1050 at least.

5. *Acetous Acid, — Acetum Distillatum, P. L. — distilled Vinegar.*

If vinegar be distilled in copper vessels, it can hardly fail being contaminated by that metal; and, if a leaden worm be used for its condensation, some portion of lead will certainly be dissolved. The former metal will appear on adding an excess of solution of pure ammonia; and lead will be detected by the sulphuretted ammonia, or by water saturated with sulphuretted hydrogen.

It is not unusual, in order to increase the acid taste of vinegar, to add sulphuric acid. This acid may be immediately discovered by solutions of barytes, which, when vinegar has been thus adulterated, throw down a white precipitate.

6. *Boracic Acid, — sedative Salt of Homberg.*

Genuine boracic acid should totally dissolve in five times its weight of boiling alcohol; and the solution, when set on fire, should emit a green flame. The best boracic acid forms small hexangular scaly crystals of a shining silvery white colour. Its specific gravity is 1480.

7. *Tartarous Acid.*

This acid often contains sulphuric acid, to discover which let a portion be dissolved in water, and a solution of acetite of lead be added. A precipitate will appear, which, if the acid be pure, is entirely redissolved by a few drops of pure nitric acid or by a little pure acetic acid. If any portion remain undissolved, sulphuric acid is the cause. Muriate of barytes, also, when the acid is adulterated with sulphuric acid, but not otherwise, gives a precipitate insoluble by an excess of muriatic acid.

8. *Acid of Amber.*

Acid of amber is adulterated, sometimes with sulphuric acid and its combinations; sometimes with tartareous acid; and at others with muriate of ammonia.

Sulphuric acid is detected by solutions of barytes; tartareous acid by carbonate of potash, which forms a difficultly-soluble tartrite; and muriate of ammonia by nitrate of silver, which discovers the acid, and by a solution of pure potash, which excites a strong smell of ammonia.

Pure acid of amber is a crystalline white salt of an acid taste, soluble in twenty-four parts of cold or eight of hot water, and is volatilized, when laid on red-hot iron, without leaving any ashes or other residue.

9. *Acid of Benzoin, — Flores Benzoes, P. L.*

This acid is not very liable to adulteration. The best has a brilliant white colour and a peculiarly-grateful smell. It is soluble in a large quantity of boiling water or alcohol, and leaves no residue when placed on a heated iron.

10. *Carbonate of Potash, — Kali Preparatum, P. L.*

The salt of tartar of the shops generally contains sulphate and muriate of potash, and siliceous and calcareous earths. It should dissolve entirely, if pure, in twice its weight of cold water; and any thing that remains undissolved may be regarded as an impurity. Sometimes one fourth of foreign admixtures may thus be detected, the greater part of which is sulphate of potash. To ascertain the nature of the adulteration, dissolve a portion in pure and diluted nitric acid: the siliceous earth only will remain undissolved. Add, to one portion of the solution, nitrate of barytes; this will detect sulphate of potash by a copious precipitate. To another portion add nitrate of silver, which will discover muriatic salts; and, to a third, oxalate or fluate of ammonia, which will detect calcareous earth.

The solution of carbonate of potash (Aqua Kali, P. L.) may be examined in a similar manner.

11. *Solution of pure Potash,—Aqua Kali Puri, P. L.*

This may be assayed, for sulphuric and muriatic salts, by saturation with nitric acid, and by the tests recommended in speaking of carbonate of potash. A perfectly pure solution of potash should remain transparent on the addition of barytic water. If a precipitate should ensue, which dissolves with effervescence in dilute muriatic acid, it is owing to the presence of carbonic acid: if the precipitate is not soluble, it indicates sulphuric acid. A redundancy of carbonic acid is also shown by an effervescence on adding diluted sulphuric acid, and an excess of lime by a white precipitate, on blowing air, from the lungs, through the solution, by means of a tobacco-pipe or a glass tube.

This solution should be of such a strength as that an exact wine pint may weigh 16 ounces troy.

12. *Carbonate of Soda,—Natron Preparatum, P. L.*

Carbonate of soda is scarcely ever found free from muriate and sulphate of soda. These may be discovered by adding, to a little of the carbonate saturated with pure nitric acid, first nitrate of barytes, to detect sulphuric acid, and afterward nitrate of silver, to ascertain the presence of muriatic acid. Carbonate of potash will be shown by a precipitate ensuing on the addition of tartareous acid to a strong solution of the alcali; for, this acid forms a difficultly-soluble salt with potash but not with soda.

13. *Solution of Carbonate of Ammonia, — Aqua Ammonia, P. L.*

This should have the specific gravity of 1150; should effervesce on the addition of acids; and should afford a strong coagulum on adding alcohol.

14. *Carbonate of Ammonia, — Ammonia Preparata, P. L.*

This salt should be entirely volatilized by heat. If any thing remain, when it is laid on a heated iron, carbonate of potash or of lime may be suspected; and these impurities are most likely to be present if the carbonate of ammonia be purchased in the form of a powder. It should therefore always be bought in solid lumps. Sulphuric and muriatic salts, lime, and iron, may be discovered by adding to the alcali, saturated with nitric acid, the appropriate tests already often mentioned.

15. *Solution of pure Ammonia in Water, — Aqua Ammoniæ Puræ, P. L. — Strong Spirit of Sal Ammoniac.*

The volatile alcali, in its purest state, exists as a gas condensible by water, and its solution in water is the only form under which it is applicable to useful purposes. This solution should contain nothing besides the volatile alcali; the alcali should be perfectly free from carbonic acid, and should be combined with water in the greatest possible proportion. The presence of other salts may be discovered by saturating a portion of the solution with pure nitric acid, and adding the tests for sulphuric and muriatic acids. Carbonic acid is shown by a precipitation on mixing the solution with one of muriate of lime; for, this earthy salt is not precipitated by pure ammonia. The only mode of determining the strength of the solution is by taking its specific gravity, which, at 60° of Faht, should be as 905, or thereabouts, to 1000.

16. *Spirit of Hartshorn, — Liquor Volatilis Cornu Cervi, P. L.*

This may be counterfeited by mixing the aqua ammoniæ puræ with the distilled spirit of hartshorn, in order to increase the pungency of its smell, and to enable it to bear an addition of water. The fraud is detected by adding alcohol to the sophisticated spirit; for, if no considerable coagulation ensues, the adulteration is proved. It may also be discovered by the usual effervescence not ensuing with acids. The solution should have the specific gravity of 1500.

17. *Sulphate of Soda, — Natron Vitriolatum, P. L. — Glauber's Salt.*

This salt ought not to contain an excess of either acid or alcali, both of which may be detected by the vegetable infusions page 164. Nor should it be mixed with earthy or metallic salts; the former of which are detected by carbonate, and the latter by prussiate, of potash. Muriate of soda is discovered by adding nitrate of barytes till the precipitate ceases, and afterwards nitrate of silver, or more simply by a solution of sulphate of silver. Sulphate of potash is discovered by its more sparing solubility. The sulphate of soda, however, being itself one of the cheapest salts, there is little risk of its being intentionally sophisticated.

18. *Sulphate of Potash,* — *Kali Vitriolatum,* P. L. — *Vitriolated Tartar.*

The purity of this salt may be ascertained by the same means as that of the former one. The little value of this salt renders it pretty secure from wilful adulteration.

19. *Nitrate of Potash,* — *Nitrum Purificatum, P. L.* — *Nitre or Salt Petre.*

Nitrate of potash is, with great difficulty, freed entirely from muriate of soda; and a small portion of the latter, except for nice chemical purposes, is an admixture of little importance. To discover muriate of soda, a solution of nitrate of silver must be added as long as any sediment is produced. The precipitate, washed and dried, must be weighed. Every hundred grains will denote 42½ of muriate of soda.

Sulphate of potash or soda may be discovered by nitrate or muriate of barytes.

20. *Muriate of Soda,* — *Common Salt.*

Common salt is scarcely ever found free from salts with earthy bases, chiefly muriates of magnesia and lime, which are contained in the brine and adhere to the crystals. The earths may be precipitated by carbonate of soda, and the precipitated lime and magnesia may be separated from each other by the rules given page 196.

21. *Muriate of Ammonia,* — *Ammonia Muriata,* P. L. — *Sal Ammoniac.*

This salt ought to be entirely volatilized, by a low heat, when laid on a heated iron. It sometimes contains sulphate of ammonia, however, which, being also volatile, cannot be thus detected. To ascertain the presence of the latter salt add the muriate or nitrate of barytes, which will indicate the sulphate by a copious and insoluble precipitate.

22. *Acetite of Potash* — *Kali Acetatum,* P. L.

Genuine acetite of potash is perfectly soluble in four times its weight of alcohol, and in thus separating from other salts that are insoluble in alcohol. The tartrite of potash (soluble tartar) is the adulteration most likely to be employed. This may be discovered by adding a solution of tartarous acid, which, if the suspected salt be present, will occasion a copious precipitate. The tartrite is also detected by its forming a precipitate with acetite of lead or muriate of barytes, soluble in acetic or muriatic acid; and sulphates by a precipitate with the same agents, insoluble in acids.

23. *Neutral Tartrite of Potash.* — *Kali Tartarizatum, P. L.* — *Soluble Tartar.*

This salt should afford a very copious precipitate on adding tartarous acid. The only salt likely to be mixed with it is sulphate of soda, which may be detected by a precipitate with muriated barytes, insoluble in diluted muriatic acid.

24. *Acidulous Tartrite of Potash.* — *Tartarum Purificatum, P. L.* — *Cream of Tartar.*

The only substance with which this salt is likely to be adulterated is sulphate of potash. To determine whether this be present, pour, on about half an ounce of the powdered crystals, two or three ounce measures of distilled water; shake the mixture frequently, and let it stand one or two hours. The sulphate of potash, being more soluble than the tartrite, will be taken up; and may be known by the bitter taste of the solution, and by a precipitate, on adding muriate of barytes, which will be insoluble in muriatic acid.

25. *Compound Tartrite of Soda and Potash,* — *Natron Tartarizatum, P. L.* — *Rochelle or Seignette's Salt.*

Sulphate of soda, the only salt with which this may be expected to be adulterated, is discovered by adding to a solution of Rochelle salt the acetite of lead or muriate of barytes. — The former, if the sulphate be present, affords a precipitate insoluble in acetous acid, and the latter one insoluble in muriatic acid.

26. *Sulphate of Magnesia,* — *Magnesia Vitriolata, P. L.* — *Epsom Salt.*

This salt is very likely to be adulterated with sulphate of soda, or Glauber's salt, which may be made to resemble the magnesian salt in appearance, by stirring it briskly at the moment it is about to crystallize. The fraud may be discovered very readily if the salt consist entirely of the sulphate of soda, because no precipitation will ensue on adding carbonate of potash. If only a part of the salt be sulphate of soda, detection is not so easy, but may still be accomplished. For, since 10 parts of pure sulphate of magnesia give between 30 and 40 of the dry carbonate, when completely decomposed by carbonate of potash, if the salt under examination afford a considerably less proportion, its sophistication may be fairly inferred : or, to discover the sulphate of soda, precipitate all the magnesia, by pure ammonia, with the aid of heat. Decant the clear liquor from the precipitate, filter it, and, after evaporation to dryness, apply such a heat as will volatilize the sulphate of ammonia, when that of soda will remain fixed.

Muriate of magnesia or of lime may be detected by the salt becoming moist when exposed to the air, and by a precipitation with nitrated silver, after nitrate of barytes has separated all the sulphuric acid and magnesia. Lime is discoverable by oxalic acid.

27. *Sulphate of Alumine,—Alum.*

Perfectly pure alum should contain neither iron nor copper. The former is manifested by adding, to a solution of alum, prussiate of potash, and the latter by an excess of pure ammonia.

28. *Borate of Soda,—Borax.*

Borate of soda, if adulterated at all, will probably be so with alum or fused muriate of soda. To discover these, borax must be dissolved in water, and its excess of alcali be saturated with nitric acid. Nitrate of barytes, added to this saturated solution, will detect the sulphuric salt, and nitrate of silver the muriate of soda.

29. *Sulphate of Iron,—Ferrum Vitriolatum, P. L.—Green Vitriol.*

If this salt should contain copper, which is the only admixture likely to be found in it, pure ammonia, added till a precipitation ceases, will afford a blue liquor. Any copper that may chance to be present, may be separated, and the salt purified, by immersing, in a solution of it, a clear polished plate of iron.

30. *Tartarized Antimony,—Antimonium Tartarizatum, P. L.—Emetic Tartar.*

A solution of this salt should afford, with acetite of lead, a precipitate perfectly soluble in dilute nitric acid. A few drops of the sulphuret of ammonia, also, should immediately precipitate a gold-coloured sulphuret of antimony.

31. *Oxygenated Muriate of Mercury,* — *Hydrargyrus Muriatus, P. L.* — *Corrosive Sublimate.*

If there be any reason to suspect arsenic in this salt, the fraud may be discovered as follows: — Dissolve a small quantity of the sublimate in distilled water; add a solution of carbonate of ammonia till the precipitate ceases, and filter the solution. If, on the addition of a few drops of ammoniated copper* to this solution, a precipitate of a yellowish green colour is produced, the sublimate contains arsenic.

32. *Muriate of Mercury,* — *Calomel, P. L.*

Calomel should be completely saturated with mercury. This may be ascertained by boiling, for a few minutes, one part of calomel with $\frac{1}{32}$d part of muriate of ammonia (sal ammoniac) in 10 parts of distilled water. When carbonate of potash is added to the filtered solution, no precipitation will ensue, if the calomel be pure. This preparation, when rubbed in an earthen mortar with pure ammonia, should become intensely black, and should exhibit nothing of an orange hue.

---

* Prepared by digesting a little verdegris in the solution of pure ammonia.

33. *Mercury, or Quicksilver,—Hydrargyrus, P. L.*

Scarcely any substance is so liable to adulteration as mercury, owing to the property which it possesses of dissolving completely some of the baser metals. This union is so strong, that they even rise along with the quicksilver when distilled. The impurity of mercury is generally indicated by its dull aspect, by its tarnishing and becoming covered with a coat of oxyd on long exposure to the air, by its adhesion to the surface of glass, and when shaken with water in a bottle by the formation of a black powder. Lead and tin are frequent impurities, and the mercury becomes capable of taking up more of these if zinc or bismuth be previously added. In order to discover lead, the mercury may be agitated with a little water, in order to oxydate that metal. Pour off the water and digest the mercury with a little acetous acid. This will dissolve the oxyd of lead, which will be indicated by a blackish precipitate with sulphurated water. Or, to this acetous solution, add a little sulphate of soda, which will precipitate a sulphate of lead, containing, when dry, 72 per cent. of metal. If only a very minute quantity of lead be present, in a large quantity of metal, it may be detected by solution in nitric acid and the addition of sulphurated water. A dark brown precipitate will ensue, and will subside if allowed to stand a few days. One part of lead may thus be separated from 15263 parts of mercury*. Bismuth is detected

---

* See Mr Accum's valuable papers on the detection of adulterations in Nicholson's Journal.

by pouring a nitric solution, prepared without heat, into distilled water; a white precipitate will appear if this metal be present. Tin is manifested, in like manner, by a weak solution of nitro-muriate of gold, which throws down a purple sediment, and zinc by exposing the metal to heat.

34. *Red Oxyd of Mercury,—Hydrargyrus Calcinatus, P. L.*

This substance is rarely found adulterated, as it would be difficult to find a substance well suited to this purpose. If well prepared, it may be totally volatilized by heat.

35. *Red Oxyd of Mercury by Nitric Acid,—Hydrargyrus Nitratus Ruber, P. L.—Red Precipitate.*

This is very liable to adulteration with minium, or red lead. The fraud may be discovered by digesting it in acetic acid, and adding to the solution sulphurated water, or sulphuret of ammonia, which produce, with the compounds of lead, a dirty dark coloured precipitate. It should also be totally volatilized by heat.

36. *White Oxyd of Mercury,—Calx Hydrargyri Alba, P. L.—White Precipitate.*

White lead is the most probable adulteration of this substance, and chalk may also be occasionally mixed with it. The oxyd of lead may be discovered as in the last article; and chalk, by adding to the dilute solution a little oxalic acid.

37. *Red Sulphurated Oxyd of Mercury,* — *Hydrargyrus Sulphuratus Ruber, P. L.* — *Factitious Cinnabar.*

This substance is frequently adulterated with red lead, which may be detected by the foregoing rules. Chalk and dragon's blood are also sometimes mixed with it. The chalk is discovered by an effervescence on adding acetic acid, and by pouring oxalic acid into the acetous solution. Dragon's blood will be left unvolatilized when the sulphuret is exposed to heat, and may be detected by its giving a colour to alcohol when the cinnabar is digested with it.

38. *Black Sulphurated Oxyd of Mercury,* — *Hydrargyrus cum Sulphure, P. L.* — *Ethiops Mineral.*

The mercury and sulphur, in this preparation, should be so intimately combined, that no globules of the metals can be discovered by a magnifier; and that, when rubbed on gold, no white stain may be communicated. The admixture of ivory black may be detected by its not being wholly volatilized by heat; or, by boiling with alcali to extract the sulphur, and afterwards exposing the residuum to heat, which ought entirely to evaporate.

39. *Yellow Oxyd of Mercury,* — *Hydrargyrus Vitriolatus, P. L.* — *Turbith Mineral.*

This preparation should be wholly evaporable; and, when digested with distilled water, the water ought not to take up any sulphuric acid, which will be discovered by muriate of barytes.

40. *Fused Nitrate of Silver,* — *Argentum Nitratum, P. L.* — *Lunar Caustic.*

The most probable admixture with this substance is nitrate of copper, derived from the employment of an impure silver. In moderate proportion this is of little importance. It may be ascertained by solution in water, and adding an excess of pure ammonia, which will detect copper by a deep blue colour.

41. *White Oxyd of Zinc,* — *Zincum Calcinatum, P. L.* — *Flowers of Zinc.*

Oxyd of zinc may be adulterated with chalk, which is discoverable by an effervescence with acetous acid, and by the precipitation of this solution with oxalic acid. Lead is detected by adding, to the acetous solution, sulphurated water, or sulphuret of ammonia. Arsenic, to which the activity of this medicine has been sometimes ascribed, is detected, also, by sulphurated water, added to the acetous solution; but in this case the precipitate has a yellow colour, and, when laid on red-hot charcoal, gives first a smell of sulphur and afterwards of arsenic.

42. *White Oxyd of Lead,* — *Cerussa, P. L.* — *White Lead.*

This is frequently sophisticated with chalk, the presence of which may be detected by cold acetous acid, and by adding, to this solution, oxalic acid. Carbonate of barytes is detected by sulphate of soda added to the same solution, very largely diluted with distilled water;

and sulphate of barytes, or sulphate of lead, by the insolubility of the cerusse in distilled vinegar.

43. *Acetite of Lead,—Cerussa Acetata, P. L.—Sugar of Lead.*

If the acetite of lead should be adulterated with acetite of lime or of barytes, the former may be detected by adding, to a dilute solution, the oxalic acid; and the latter by sulphuric acid, or solution of sulphate of soda, added to a solution very largely diluted with water. Acetite of lead ought to dissolve entirely in water, and any thing that resists solution may be regarded as an impurity.

44. *Green Oxyd of Copper,—Verdegris.*

This oxyd is scarcely ever found pure, being mixed with pieces of copper, grape-stalks, and other impurities. The amount of this admixture of insoluble substances may be ascertained by boiling a portion of verdegris with 12 or 14 times its weight of distilled vinegar, allowing the undissolved part to settle, and ascertaining its weight. Sulphate of copper may be detected by boiling the verdegris with water and evaporating the solution. Crystals of acetite of copper will first separate, and, when the solution has been farther concentrated, the sulphate of copper will crystallize. Or, it may be discovered by adding to the watery solution muriate of barytes, which will throw down a very abundant precipitate. Tartrite of copper, another adulteration sometimes met with, is discovered by dissolving a little of the verdegris in acetous acid, and adding acetite or muriate of barytes, which will afford, with the tartarous acid, a precipitate soluble in muriatic acid.

45. *Crystallized Acetite of Copper,—Distilled or Crystallized Verdegris.*

This is prepared by dissolving the common verdegris in distilled vinegar, and crystallizing the solution. These crystals should dissolve entirely in six times their weight of boiling water, and the solution should give no precipitation with solutions of barytes; for, if these solutions throw down a precipitate, sulphate of copper is indicated. This impurity, which I have frequently met with, may be discovered by evaporating the solution very low, and separating the crystals of acetite of copper. Farther evaporation and cooling will crystallize the sulphate, if any be present.

46. *Carbonate of Magnesia,—Magnesia Alba,* P. L.

Carbonate of magnesia is most liable to adulteration with chalk; and, as lime forms with sulphuric acid a very insoluble salt, and magnesia one very readily dissolved, this acid may be employed in detecting the fraud. To a suspected portion of magnesia add a little sulphuric acid, diluted with 8 or 10 times its weight of water. If the magnesia should entirely be taken up, and the solution should remain transparent, it may be pronounced pure, but not otherwise. Another mode of discovering the deception is as follows:—saturate a portion of the suspected magnesia with muriatic acid, and add a solution of carbonate of ammonia. If any lime be present, it will form an insoluble precipitate, but the magnesia will remain in solution.

47. *Pure Magnesia, — Magnesia Usta, P. L. — Calcined Magnesia.*

Calcined magnesia may be assayed by the same tests as the carbonate. It ought not to effervesce at all with dilute sulphuric acid; and, if the earth and acid be put together into one scale of a balance, no diminution of weight should ensue on mixing them together. It should be perfectly free from taste, and, when digested with distilled water, the filtered liquor should manifest no property of lime-water. Calcined magnesia, however, is very seldom so pure as to be totally dissolved by diluted sulphuric acid, for a small insoluble residue generally remains, consisting chiefly of siliceous earth, derived from the alcali. The solution in sulphuric acid, when largely diluted, ought not to afford any precipitation with oxalate of ammonia.

48. *Spirit of Wine, Alcohol, and Æthers.*

The only decisive mode of ascertaining the purity of spirit of wine and of æthers, is by determining their specific gravity. Highly-rectified alcohol should have the specific gravity of 829 to 1000. Common spirit of wine 837. Sulphuric æther 739. The spiritus ætheris vitriolicus, P. L. or sweet spirit of vitriol, about 753, — and nitric æther, the spiritus ætheris nitrosus, or sweet spirit of nitre, 908. The æthers ought not to redden the colour of litmus, nor ought those formed from sulphuric acid to give any precipitation with solutions of barytes.

19. *Essential or volatile Oils.*

As essential oils constitute only a very small proportion of the vegetables from which they are obtained, and bear generally a very high price, there is a considerable temptation to adulterate them. They are found sophisticated, either with cheaper volatile oils, with fixed oils, or with spirit of wine. The fixed oils are discovered by distillation with a very gentle heat, which elevates the essential oils, and leaves the fixed ones. These last may, also, be detected by moistening a little writing paper with the suspected oil, and holding it before the fire. If the oil be entirely essential, no stain will remain on the paper. Alcohol, also, detects the fixed oils, because it only dissolves the essential ones, and the mixture becomes milky. The presence of cheaper essential oils is discovered by the smell. Alcohol, a cheaper liquid than some of the most costly oils, is discovered by adding water, which, if alcohol be present, occasions a milkiness.

SECT. III. — *Use of Chemical Reagents to certain Artists and Manufacturers.*

To point out all the beneficial applications of chemical subtances to the purposes of the arts, would require a distinct and very extensive treatise. In this place I have no farther view than to describe the mode of detecting adulterations in certain articles of commerce, the strength and purity of which are essential to the success of chemical processes.

1. *Mode of detecting the Adulteration of Pot-ashes, Pearl-ashes, and Barilla.*

Few objects of commerce are sophisticated to a greater extent than the alcalis, to the great loss and injury of the bleacher, the dyer, the glass-maker, the soap-boiler, and of all other artists who are in the habit of employing these substances. In the first part of this work (see page 55) I have already given rules for discovering such adulterations; and to what has been said, I apprehend, it is only necessary to add the directions of Mr Kirwan, intended to effect the same end, but differing in the mode. They are transcribed from his paper entitled "Experiments on the Alcaline Substances used in Bleaching;" — see Transactions of the Irish Academy for 1789.

"To discover whether any quantity of fixed alcali worth attention exists in any saline compound, dissolve one ounce of it in boiling water, and into this solution let fall a drop of a solution of sublimate corrosive; this will be converted into a brick-colour, if an alcali be present, or into a brick-colour mixed with yellow, if the substance tried contains lime.

"But the substances used by bleachers being always impregnated with an alcali, the above trial is in general superfluous, except for the purpose of detecting lime. The quantity of alcali is therefore what they should chiefly be solicitous to determine, and for this purpose:

"1st. Procure a quantity of alum, suppose one pound, reduce it to powder, wash it with cold water, and then put it into a tea-pot, pouring on it three or four times its weight of boiling water.

" 2dly. Weigh an ounce of the ash or alcaline substance to be tried, powder it, and put it into a Florence flask with one pound of pure water, (common water, boiled for a quarter of an hour and afterwards filtered through paper, will answer,) if the substance to be examined be of the nature of barilla or potash, or half a pound of water if it contain but little earthy matter, as pearl-ash. Let them boil for a quarter of an hour; when cool let the solution be filtered into another Florence flask.

" 3dly. This being done, gradually pour the solution of alum hot into the alcaline solution also heated; a precipitation will immediately appear; shake them well together, and let the effervescence, if any, cease before more of the aluminous solution be added; continue the addition of the alum until the mixed liquor, when clear, turns syrup of violets, or paper tinged blue by radishes, or by litmus, red; then pour the liquor and precipitate on a paper filter placed in a glass funnel. The precipitated earth will remain on the filter; pour on this a pound or more of hot water, gradually, until it passes tasteless; take up the filter, and let the earth dry on it until they separate easily. Then put the earth into a cup of Staffordshire ware, place it on hot sand, and dry the earth until it ceases to stick to glass or iron; then pound it, and reduce it to powder in the cup with a glass pestle, and keep it a quarter of an hour in a heat of from 470° to 500°.

" 4thly. The earth being thus dried, throw it into a Florence flask and weigh it; then put about one ounce of spirit of salt into another flask, and place this in the same scale as the earth, and counterbalance both in the opposite scale: this being done, pour the spirit of salt gradually into the flask that contains the earth; and, when all effervescence is over, (if there be any,) blow into the flask, and observe what weight must be added to the scale containing the flasks to restore the equilibrium; subtract this weight from that of the earth, the remainder is a weight exactly *proportioned* to the weight of mere alcali of that particular species which is contained in one ounce of the substance examined all beside is superfluous matter.

" I have said that alcalies of the *same species* may thus be directly compared, because alcalies of *different* species cannot but require the intervention of another proportion; and the reason is, because *equal* quantities of alcalies of different species precipitate unequal quantities of earth of alum: thus 100 parts by weight of mere vegetable alcali precipitate 78 of earth of alum, but 100 parts of *mineral* alcali precipitate 170·8 parts of that earth. Therefore the precipitation of 78 parts of earth of alum, by vegetable alkali, denotes as much of this as the precipitation of 170·8 of that earth by the mineral alcali denotes of the mineral alcali. Hence the quantities of alcali in all the different species of pot-ashes, pearl-ashes, weed or wood ashes, may be immediately compared with the above test, as they all contain the vegetable alcali; and the different kinds of kelp or kelps manufactured in different places, and the different sorts of barilla, may thus be compared, because they all contain the mineral alcali. But kelps and pot-ashes, as they contain different sorts of alcali, can only be compared together by means of the proportion above indicated."

2. *Mode of detecting the Adulteration of Manganese.*

In the section on drugs, instructions may be found for discovering impurities in several chemical preparations, employed by the artist, as cerusse or white lead, red lead, verdegris, &c. No rules, however, have been given for examining manganese, which is a substance that varies much in quality, and is often sophisticated; as the bleachers experience, to their no small disappointment and loss.

The principal defect of manganese arises from the admixture of chalk, which is not always an intentional adulteration, but is sometimes found united with it, as it occurs in the earth. When to this impure manganese, mixed with muriate of soda, (see page 85,) the sulphuric acid is added, the materials effervesce and swell considerably, and a large proportion passes into the receiver; in consequence of which the bleaching liquor is totally spoiled. This misfortune has, to my knowledge, frequently happened, and can only be prevented by so slow and cautious an addition of the acid, as is nearly inconsistent with the business of an extensive bleaching work. The presence of carbonate of lime may be discovered in manganese, by pouring, on a portion of this substance, nitric acid diluted with 8 or 10 parts of water. If the manganese be good, no effervescence will ensue, nor will the acid dissolve any thing; but, if carbonate of lime be present, it will be taken up by the acid. To the solution add a sufficient quantity of carbonate of potash to precipitate the lime, wash the sediment with water, and dry it. Its weight will show how much chalk the manganese under examination contained.

Another adulteration of manganese, that may, perhaps, be sometimes practised, is the addition of some ores of iron. This impurity is less easily discovered. But if the iron be in such a state of oxydation as to be soluble in muriatic acid, the following process may discover it. Dissolve a portion, with the assistance of heat, in concentrated muriatic acid, dilute the solution largely with distilled water, and add a solution of crystallized carbonate of potash. The manganese will remain suspended, by the excess of carbonic acid, on mixing the two solutions, but the iron will be precipitated in the state of a coloured oxyd.

From an observation of Klaproth (Essays, p. 572) it appears that oxyds of iron and manganese are separable by nitrous acid with the addition of sugar, which takes up the manganese only.

SECT. IV.—*Application of chemical Tests to the Uses of the Farmer and Country Gentleman.*

The benefits, that might be derived from the union of chemical skill with extensive observation of agricultural facts, are, perhaps, incalculable. At present, however, the state of knowledge among farmers is not such as to enable them to reap much advantage from chemical experiments, and the chemist has, himself, scarcely ever opportunities of applying his knowledge to practical purposes in this way. It may, perhaps, however, be of use to offer a few brief directions for the analysis of marls, lime-stones, &c.; and, on this occasion, I shall owe much of my information, as in various other parts of this work, to the writings of Mr Kirwan, whose pamphlet on philosophical agriculture I strongly recommend to general perusal *.

1. *Lime.*

It is impossible to lay down any general rules respecting the fitness of lime for the purposes of agriculture, because much must depend on the peculiarities of soil, exposure, and other circumstances. Hence a species of lime may be extremely well adapted for one kind of land and not for another. All that can be accomplished by chemical means is to ascertain the degree of purity of the lime, and to infer, from this, to what kind of soil it is best adapted. Thus a lime, which contains much argillaceous earth, is better adapted than a purer one to dry and gravelly soils; and stiff clayey lands require a lime as free as possible from the argillaceous ingredient.

To determine the purity of lime, let a given weight be dissolved in diluted muriatic acid. Let a little excess of acid be added, that no portion may

---

* It is entitled, "The Manures most advantageouſly applicable to the various sorts of soils, and the causes of their beneficial effects in each particular inſtance. By R. Kirwan, Esq. — London, 1796."

remain undissolved owing to the deficiency of the solvent. Dilute with distilled water; let the insoluble part, if any, subside, and the clear liquor be decanted. Wash the sediment with farther portions of water, and pour it upon a filter previously weighed. Dry the filter, and ascertain its increase of weight, which will indicate how much insoluble matter the quantity of lime submitted to experiment contained. It is easy to judge by the external qualities of the insoluble portion whether argillaceous earth abounds in its composition.

There is one earth, however, lately found in several lime-stones, which is highly injurious to the vegetation of plants, and is not discoverable by the foregoing process, being, equally with lime, soluble in muriatic acid. This earth is magnesia, which, by direct experiments, has been ascertained to be extremely noxious to plants. Mr Tennant, the gentleman to whom we owe this fact, was informed, that in the neighbourhood of Doncaster two kinds of lime were employed, one of which it was necessary to use very sparingly, and to spread very evenly; for, it was said that a large proportion, instead of increasing, diminished the fertility of the soil; and that, whenever a heap of it was left in one spot, all fertility was prevented for many years. Fifty or sixty bushels on an acre were considered to be as much as could be used with advantage. The other sort of lime, which was obtained from a village near Ferrybridge, though considerably dearer, from the distant carriage, was more frequently employed, on account of its superior utility. A large quantity was never found to be injurious; and the spots, which were covered with it, instead of being rendered barren, became remarkably fertile. On examining the composition of these two species of lime, the fertilizing one proved to consist entirely of calcareous earth, and the noxious one of three parts lime and two magnesia.

The presence of magnesia in lime proved, on farther investigation, to be a very common occurrence. The magnesian lime-stone appears to extend for 30 or 40 miles from a little south-west of Worksop, in Nottinghamshire, to near Ferrybridge, in Yorkshire, and it has also been found at Breedon and Matlock, in Derbyshire.

The magnesian lime-stone, according to Mr Tennant, may easily be distinguished from that which is purely calcareous by the slowness of its solution in acids, which is so considerable, that even the softest kind of the former is much longer in dissolving than marble. It has also frequently a crystallized structure, and sometimes, though not always, small black dots may be seen dispersed through it. In the countries where this lime-stone is found, the lime is generally distinguished, from its effects in agriculture, by the farmers, as *hot* lime, in opposition to the purely calcareous, which they term *mild*.

To ascertain, by chemical means, the composition of a lime or lime-stone suspected to contain magnesia, the following is the easiest, though not the most accurate, process. Procure a Florence flask, clean it well from oil by a little soap-lees or salt of tartar and quick-lime mixed, and break it off, about the middle of the body, by setting fire to a string tied round it and moistened with oil of turpentine. Into the bottom part of this flask put 100 grains of the lime or lime-stone, and pour on it, by degrees, half an ounce of strong sulphuric acid. On each affusion of acid a violent effervescence will ensue; when this ceases, stir the acid and lime together with a small glass tube or rod, and place the flask in an iron pan filled with sand. Set it over the fire, and continue the heat till the mass is quite dry. Scrape off the dry mass, weigh it, and put it into a wine-glass, which may be filled up with water. Stir the mixture, and, when it has stood half an hour, pour the whole on a filtering-paper, placed on a funnel, and previously weighed. Wash the insoluble part with water, as it lies on the filter, and add the washings to the filtered liquor. To this liquor add a solution of half an ounce of salt of tartar in water, when, if magnesia be present, a very copious white sediment will ensue, if lime only, merely a slight milkiness. In the former case, heat the liquor, by setting it in a teacup near the fire, let the sediment subside, pour off the clear liquor, which may be thrown away, and wash the white powder, repeatedly, with warm water. Then pour it on a filter of paper, the weight of which is known, dry it, and weigh. The result, if the limestone has been submitted to experiment, shows how much carbonate of magnesia was contained in the original stone; or, deducting 60 per cent. how much pure magnesia 100 parts of the lime-stone contained. If the burnt lime has been used, deduct from the weight of the precipitate 60 per cent. and the remainder will give the weight of the magnesia in each 100 grains of the burnt lime.

2. *Analysis of Marls.*

The ingredient of marls, on which their fitness for agricultural purposes depends, is the carbonate of lime. It is owing to the presence of this earth that marls effervesce on the addition of acids, which is one of their distinguishing characters. In ascertaining whether an effervescence takes place, let the marl be put into a glass partly filled with water, which will expel a portion of air contained mechanically in the marl, and thus obviate one source of fallacy. When the marl is thoroughly penetrated by the water, add a little muriatic acid or spirit of salt. If a discharge of air should ensue, the marly nature of the earth is sufficiently established.

To find the composition of a marl, pour a few ounces of diluted muriatic acid into a Florence flask, place them in a scale, and let them be balanced. Then reduce a few ounces of dry marl into powder, and let this powder be carefully and gradually thrown into the flask, until, after repeated additions, no farther effervescence is perceived. Let the remainder of the powdered marl be weighed, by which the quantity projected will be known. Let the balance be then restored. The difference of weight between the quantity projected and that requisite to restore the balance will show the weight of air lost during effervescence. If the loss amount to 13 per cent. of the quantity of marl projected, or from 13 to 32 per cent. the marl assayed is calcareous marl, or marl rich in calcareous earth, Clayey marls, or those in which the argillaceous ingredient prevails, lose only 8 or 10 per cent. of their weight by this treatment, and sandy marls about the same proportion. The presence of much argillaceous earth may be judged by drying the marl, after being washed with spirit of salt, when it will harden and form a brick.

To determine, with still greater precision, the quantity of calcareous earth in a marl, let the solution in muriatic acid be filtered and mixed with a solution of carbonate of potash, till no farther precipitation appears. Let the sediment subside, wash it well with water, lay it on a filter, previously weighed, and dry it. The weight of the dry mass will show how much carbonate of lime the quantity of marl submitted to experiment contained.

3. *Analysis of Soils.*

The following rules, for determining the composition of a soil, are copied from the interesting tract of Mr Kirwan already referred to.

"1mo. In dry weather, when the soil is not over moist nor dry, let a surface of 16 square inches be cut through to the depth of 8 inches; this may be effected by a right-angled spade, formed for this particular purpose. Of the parallelopiped thus dug up the two inches next the surface should be cut off, to get rid of the grass and the greater part of the roots; we shall then have a solid 6 inches long and 16 square at the end, = 96 cubic inches. Let this be weighed*; its

---

* Troy weights are generally more exactly made than avoirdupois, and therefore should be preferred. A cubic foot of pure

weight will serve to find the specific gravity of the soil; for, if 96 cubic inches weigh *n* pounds, 1728 (a cubic foot) should weigh *x* pounds, and *x* divided by 75·954 will express, by the quotient, the specific gravity of the soil. To render this and the subsequent operations more intelligible, I shall illustrate each by an example: — Suppose the 96 cubic inches to weigh 6·66 pounds, then 1728 cubic inches should weigh

$$120 \text{ lb. and } \frac{120}{75\cdot954.} = 1\cdot579.$$

2°. The earth being weighed is next to be broken down and freed from all stony substances above the size of a pippin, and the remainder well mixed together, to render the whole as homogeneous as possible; then weigh the stones that were picked out, and find the proportion belonging to each pound of the residuary earth; call this the *stoney supplement*, and denote it by S. Thus, if the stones weigh 1 lb. = 12 oz. the remainder, or mere earth, must weigh 5·66 lb.; and if to 5·66 lb, there belong 12 oz. of stone, to 1 lb. must belong 2·12014 oz. or 2 oz. 57·66 gr. = 1017·66 gr. This, then, is the stoney supplement of each succeeding pound, = S.

3°. Of the earth thus freed from stoney matter take 1 lb. — S. (that is, in the above case, 1 lb. — 2 oz. $57\frac{2}{3}$ gr.) heat it nearly to redness in a flat vessel, often stirring it for half an hour, and weigh it again when cold. Its loss of weight will indicate the quantity of water contained in 1 lb. of the soil. Note this loss and

---

water weighs 75·954 Troy, very nearly, or 62·5 avoirdupois, pounds, at the temperature 62°.

call it the *watery supplement*, = W. Suppose it in this case 100 grains.

" 4°. Take another pound of the above mass freed from stones, deducting the stoney and watery supplements, that is, 1lb.—S—W, or in the above case 1 lb. — 2 oz. $57\frac{2}{3}$ grs for stone, and — 100 grs for water; consequently, 1 lb. — 2 oz. $157\frac{2}{3}$ grs reduce it to powder: boil it in four times its weight of distilled water for half an hour; when cool, pour it off, first into a coarse linen filter to catch the fibrous particles of roots, and then through paper, to catch the finer clayey particles diffused through it; set by the clear water, add what remains on the filter to the boiled mass; if it be insipid, as I suppose it to be, then weigh the fibrous matter, and call it the *fibrous supplement*, = F. Suppose it in the example in hand to weigh 10 grs.

" 5°. Take two other pounds of the mass freed from stoney matter, No. II. subtracting from them the weight of the stoney, watery, and fibrous, substances already found; that is, 2lb—2S—2W—2F; pour twice their weight of warm distilled water on them, and let them stand twenty-four hours or longer, that is, until the water has acquired a colour, then pour it off, and add more water as long as it changes colour; afterwards filter the coloured water and evaporate it to a pint, or half a pint, set it in a cool place for three days, then take out the saline matter, if any be found, and set it by.

" 6°. Examine the liquor out of which the salts have been taken; if it do not effervesce with the marine acid, evaporate it to dryness, and weigh the residuum; if it do effervesce with acids, saturate it with the vitriolic or marine, and evaporate it to one fourth of the whole; when cool, take out the saline residuum, evaporate the remainder to dryness, and weigh it; this gives the coaly matter, which may be tried by projecting it on melted nitre, with which it will deflagrate. The half of this coaly matter call the *coaly supplement* of 1lb. I shall suppose it to amount to 12 grs. and denote it by C.

" 7°. The filtered water, No. IV. is next to be gently evaporated to nearly one pint, and then suffered to rest for three days in a cool place, that it may deposit its saline contents, if it contain any; and these being taken out, the remainder must be evaporated nearly to dryness, and its saline and other contents examined. How this should be done I shall not mention, the methods being too various, tedious, and of too little consequence; few salts occur except gypsum, which is easily distinguished. The water may be examined as to its saline contents when it is evaporated to a pint; if any salts be found, call them the *saline supplement*, and denote them by S. I shall suppose them, here, =4 grains.

" 8°. We now return to the boiled earthy residuum, No. IV. which we shall suppose fully freed from its saline matter; as, if it be not, it may easily be rendered so by adding more hot water; let it then be dried as in No. III. is mentioned. Of this earthy matter, thus dried, weigh off one ounce, deducting one twelfth part of each of the supplements S. W. F. C. and S.; that is, in this case,

$$\frac{1017{\cdot}66}{12} = 84{\cdot}4054 + \frac{100}{12} = 8{\cdot}333 + \frac{10}{12}$$
$$= 0{\cdot}8333 + \frac{12}{12} = 1 + \frac{4}{12} = 0{\cdot}3333 = 95 \text{ gr.}$$

in all: then 480 — 95 = 385 grains, will remain and represent the mere earthy matter in an ounce of the soil.

"9°. Let this remainder be gradually thrown into a Florence flask, holding one and a half as much spirit of nitre as the earth weighs, and also diluted with its own weight of water (the acids employed should be freed from all contamination of the vitriolic acid): the next day, the flask with its contents being again weighed, the difference between the weights of the ingredients and the weights now found will express the quantity of air that escaped during the solution. Thus, in the above case, the earth weighing 385 grains, the acid 577·5 grains, and the water 577·5 grains, in all 1540 grains, the weight, after solution, should also be 1540, if nothing escaped: but, if the soil contains calcareous matter, a loss will always be found after solution. Let us suppose it to amount to 60 grains.

"The weight of air that escaped furnishes us with one method of estimating the quantity of calcareous matter contained in the earth assayed; for mild calx generally contains 40 per cent. of air: then, if 40 parts air indicate 100 of calcareous matter, 60 parts air will indicate 150*.

---

* I take no account of magnesia, as, in agriculture, I believe it of little importance.

"10°. The solution is then to be carefully poured off and the undissolved mass washed and shaken in distilled water, the whole thrown on a filter, and washed as long as the water that passes through has any taste. The contents of this water should be precipitated by a solution of mild mineral alcali: this precipitate, also, being washed, and dried in a heat below redness, should then be weighed. Thus, we have another method of finding the weight of the calcareous matter.

"11°. The undissolved mass is next to be dried, in the heat already mentioned, and the difference between its weight and the weight of the whole earthy mass before solution should be noted, as it furnishes a third method of discovering the weight of the calcareous matter of which it is now deprived. Supposing this to amount to 150 grains, the weight of the undissolved residuum should, in the above case, be 383 — 150 = 235 grains.

"12°. Reduce the dried mass into the finest powder, throw it into a Florence flask or glass retort, and pour on it three times its weight of pure oil of vitriol, digest in a strong sand heat, and, at last, raise the heat so as to make the acid boil; afterwards let it evaporate nearly to dryness: when cold, pour on it, gradually, six or eight times its weight of distilled water, and, after some hours, pour off the solution on a filter; the filter should previously be weighed and its edges soaked in melted tallow*; the substance found on the filter being weighed (subtracting the weight of the filter)

---

* An ingenious contrivance of Dr Black.

gives the quantity of silicious matter, and this weight, subtracted from that of the dried mass, gives that of the argill. In this case I will suppose the silicious mass to weigh 140 grains, then the argillaceous should weigh 95 grains.

"Then the composition of one pound of the soil is as follows:

Stoney matter		1017·66
Water		100
Fibres of roots		10
Soluble coal		12
Saline matter		4
Silex	140 × 12 =	1680
Argill	95 × 12 =	1140
Mild calx	150 × 12 =	1800
		5763·66 *

And in centesimal proportion

Stoney matter	18
Fine silicious	29
	47
Argill	22
Mild calx	31
	100

Its retentive power is 82·25: hence I should judge it to be unfertile in this climate, unless situated on a declivity, with an unimpeded fall. It may be called a *clayey loam*.

Mr Young discovered a remarkable circumstance attendant on fertile soils: he found that equal weights of

---

* An error of 3·66 grains for decimals omitted in subtractions.

different soils, being dried and reduced to powder, afforded quantities of air by distillation somewhat corresponding to the ratios of their values. This air was a mixture of fixed and inflammable airs, both proceeding, most probably, from the decomposition of water by the coaly matter in the soil. The distillation should be made from a retort glazed on the outside. He found an ounce of dry soil, value five shillings, produced ten ounce measures :

Of value of from 5 to 12s. produced 28 oz.
12 — 20 42
above 20 66

This appears to be a good method of estimating the proportion of coaly matter in soils that are in full heart; that is, not exhausted, and freed from roots, &c. Another mark of the goodness of a soil is the length of the roots of wheat growing in it: for these are in inverse proportion to each other, as, if the land be poor, the wheat will extend its roots to a great distance in quest of food; whereas, if it be rich, they will not extend above five or six inches; but of these and some other empyrical marks I shall say no more, as they do not tell us the defects of the soils."

SECT. V. *Miscellaneous Uses of chemical Reagents.*

1. *Removal of ink stains.* The stains of ink on cloth, paper, or wood, may be removed by almost all acids; but those acids are to be preferred which are least likely to injure the texture of the stained substance. The muriatic acid, diluted with 5 or 6 times its weight of water, may be applied to the spot, and, after a

minute or two, may be washed off, repeating its application as often as may be found necessary. But the vegetable acids are attended with less risk and are equally effectual. A solution of the oxalic, citric, or tartarous, acids in water, may be applied to the most delicate fabrics, without any danger of injuring them; and the same solutions discharge, from paper, written but not printed ink. Hence they may be employed in cleaning books, which have been defaced by writing on the margin, without impairing the text.

2. *Iron stains.* These may be occasioned either by ink stains, which, on the application of soap, are changed into iron stains, or by the direct contact of rusted iron. They may be removed by diluted muriatic acid, or by one of the vegetable acids already mentioned. When suffered to remain long on cloth, they become extremely difficult to take out, because the iron, by repeated moistening with water and exposure to the air, acquires such an addition of oxygen as renders it insoluble in acids. I have found, however, that even these spots may be discharged, by applying first a solution of an alcaline sulphuret, which must be well washed from the cloth, and afterwards a liquid acid. The sulphuret, in this case, extracts part of the oxygen from the iron and renders it soluble in dilute acids.

3. *Fruit and wine stains.* These are best removed by a watery solution of the oxygenated muriatic acid, (see page 85.) or by that of oxygenated muriate of potash or lime, to which a little sulphuric acid has been added. The stained spot may be steeped in one of these solutions till it is discharged; but the

solution can only be applied with safety to white goods, because the uncombined oxygenated acid discharges all printed and dyed colours. A convenient mode of applying the oxygenated acid, easily practicable by persons who have not the apparatus for saturating water with the gas, is as follows: — Put about a table spoonful of muriatic acid (spirit of salt) into a tea-cup and add to it about a tea spoonful of powdered manganese. Then set this cup in a larger one filled with hot water. Moisten the stained spot with water, and expose it to the fumes that arise from the tea cup. If the exposure be continued a sufficient length of time, the stain will disappear.

Stains on silk may be removed by a watery solution of sulphureous acid.

4. *Spots of grease* may be removed by a diluted solution of pure potash; but this must be cautiously applied, to prevent injury to the cloth. Stains of *white wax*, which sometimes fall upon the clothes from wax candles, are removable by spirit of turpentine or sulphuric ether. The marks of *white paint* may also be discharged by the last-mentioned agents.

INDEX.

ERRATA.—P. 94, lines 6 and 3 from bottom, *for* phosphorus *read* phosphoreous.

Printed by C. and W. Galabin, Ingram-court, London.

LIST OF
ELEMENTARY BOOKS
ON
CHEMISTRY.

THE following list comprehends a selection of a few elementary works on chemistry, which are sufficient for the purpose of the general reader. To have offered the catalogue of a complete chemical library would have occupied too much room, and perhaps would not have been of much utility.

1. Lavoisier's Elements of Chemistry, 8vo.
2. ——— Works, from the French, by Henry, 1 vol. 8vo. and a pamphlet.
3. Chaptal's Elements of Chemistry, 3 vol. 8vo.
4. Nicholson's First Principles of Chemistry, 8vo.
5. ——— Chemical Dictionary, 2 vol. 4to.
6. Thomson's Translation of Fourcroy's Chemistry, 3 vol. 8vo.
7. Gren's Principles of Chemistry, 2 vol. 8vo.
8. La Grange's Manual of Chemistry, 2 vol. 8vo.
9. Pearson's Chemical Nomenclature, second edition, 4to.
10. Parkinson's Chemical Pocket-book.
11. Nicholson's Philosophical Journal, published monthly.
12. Philosophical Magazine, published monthly.
13. A System of Chemistry, by Thomas Thomson, M. D. 4 vol. 8vo.
14. Elements of Chemistry, by J. Murray, 2 vol. 8vo.
15. Remarks on Chemical Nomenclature, by R. Chenevix, Esq. F.R.S. &c.

To the above may be added a large work, lately published, in France, by M. Fourcroy, and which Mr Nicholson is now translating. It will be entitled "A System of Chemical Knowledge," and will extend to 10 volumes 8vo.

Of J. JOHNSON,

No. 72,

ST PAUL'S CHURCHYARD, LONDON,

may be had

THE FOLLOWING WORKS,

By Thomas Henry, F.R.S. &c.

1. An Account of a Method of preserving Water at Sea, 8vo, pamphlet, 2s.

2. Experiments and Observations on the following subjects:

1. On the preparation, calcination, and medicinal use, of Magnesia.
2. On the solvent qualities of calcined Magnesia.
3. On the variety in the solvent powers of Quick-lime, when used in different quantities.
4. On various absorbents as promoting or retarding putrefaction.
5. On the comparative antiseptic powers of Vegetable Infusions prepared with Lime, &c.
6. On the sweetening properties of Fixed Air.

8vo. price 2s. 6d.

3. Essays Physical and Chemical, by M. Lavoisier, translated from the French, 8vo. 7s.

4. Essays on the Effects produced by various Processes, on Atmospheric Air, with a particular View to

an Investigation of the Constitution of Acids, translated from the French of Lavoisier, 8vo. 2s. 6d.

N. B. The two foregoing works afford an historical view of the progress of pneumatic chemistry; and a full and very interesting development of those accurate and admirably-conceived experiments of M. Lavoisier, which serve as the basis of the reformed system of chemical science.

5. Memoirs of Albert de Haller, 12mo. 3s.

IN THE PRESS,

And will be published in MARCH or APRIL, 1803,

A HISTORY

OF THE

ORIGIN, PROGRESS, AND PRESENT STATE,

OF

ANIMAL CHEMISTRY.

To which is added,

A CHEMICAL INVESTIGATION OF SEVERAL OF THE FUNCTIONS OF ANIMAL LIFE.

BY

W. B. Johnson, M. B.

DESCRIPTION AND PRICES OF THE PORTABLE CHEMICAL CHESTS,

Invented by William Henry, and sold by him at his Laboratory, in Manchester.

No. 1. A large double mahogany chest, with folding doors, containing ninety-one strong square bottles, with ground stoppers, filled with tests, &c. and so arranged that the labels may be seen at one view; together with five drawers, in which are various articles of apparatus; accurate scales, decimal weights, improved blow-pipe and spoon, complete, . . 20 *guineas.*

No. 2. An upright chest, box shaped, intended chiefly as a travelling companion, holding thirty-six bottles, with a drawer containing articles and apparatus, as in the two foregoing ones, ... 7 *guineas.*

N. B. Any one of the foregoing chests may be had either with or without the scales and blow-pipe. If sold without scales and weights, 16 shillings may be deducted from the foregoing prices, and 14 for the blow-pipe and spoon.

The tests are all prepared with the most scrupulous attention to accuracy; and supplies may be obtained, by purchasers of the chests, when the stock they contain is exhausted.

Letters, containing orders for the chests, which will be sent, carefully packed, to any part of Great Britain, to be post paid, and a remittance of the value will be expected before the chest is delivered to the carrier.

A
LIST
OF
CHEMICAL TESTS, PREPARATIONS, AND INSTRUMENTS,

SOLD BY

W. AND S. JONES,

No. 135, *Holborn, London.*

A Humid Laboratory, or a Mahogany Portable Cheſt, containing, in 56 cloſe-ſtopped glaſs phials, Fluid Teſts, Re-agents, and Fluxes for the Blow-Pipe, &c. all of genuine preparations, for analyſing Mineral Waters, examining Mineral Bodies, and for many other uſeful Chemical experiments	£.5	5	0
Cheſts of ditto, with a leſs number of Teſts, from 2*l.* 2*s.* to	3	3	0
Gotling's Deſcription of the above Portable Cheſt of Chemiſtry, bound	0	4	0
A Portable Cheſt, of 28 phials, containing chemical preparations for performing a variety of entertaining and inſtructive experiments with ſympathetic inks, dyes, phoſphoric exhibitions, &c. with a printed book of directions	3	13	6
Pipe, with various caps for fluxing ls, &c.	0	7	6

A Pocket Dry Laboratory, containing a Blow-Pipe, Fluxes, Silver Spoon, Magnet, Megallacope, and other uſeful articles for the examination of Mineral Bodies - -	2	12	6
A Portable Lamp Furnace, containing a blow-pipe, ſupport and ſtand, ſmall glaſs retorts, mattreſſes, &c. &c. to perform chemical experiments in miniature, as well as for mineralogical purpoſes. (See Cronſtedt's Mineralogy, by Magellan, 2 vols. 1788.) - -	4	14	6
Ditto, with double bellows for different airs, to uſe with the blow-pipe - - -	7	7	0
A Pneumatic Apparatus, containing a wooden ciſtern, glaſs bottles with bent necks, glaſs jars, retorts, receivers, a portable iron chafing diſh, &c. &c. for performing the new-diſcovered experiments on airs - - -	6	6	0
A Glaſs Machine for impregnating water with fixed air, &c. and all the auxiliary apparatus	2	12	6
Two Bladders with Braſs Stopcocks, connecting piece, plain pipe and circular jet for containing inflammable, &c. airs, and exhibiting their beautiful effects - - - -	1	2	0

Eudiometers, or Gazometers, from the moſt eminent Writers.

For a general Collection of Optical, Mathematical, and Philoſophical Inſtruments, ſee the Catalogue of W. and S. JONES, to be had gratis.