Wm W. Boardman
Novr 1810

Wm W Boardman

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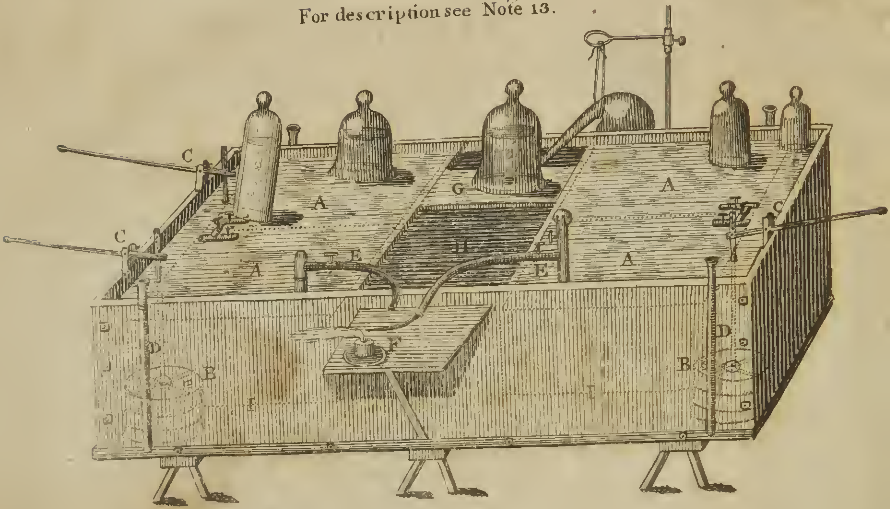
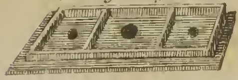
Frontispiece

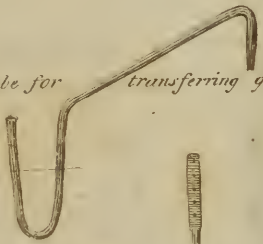
Pneumatic Cistern of Yale College

For description see Note 13.

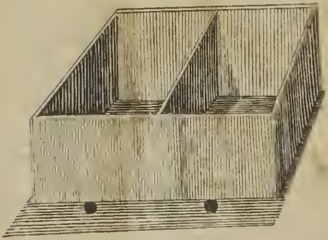


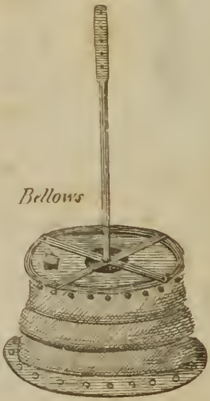

Blow pipe tube


Sliding shelf inverted


Bent tube for transferring gases


Compound blow-pipe for oxigen & hidrogen


Gas boxes inverted


Bellows

Drawn & engraved by A. Doolittle, from the Original, constructed by Professor Sillimán,
and invented by him & Mr. Hare.

Published by Wm. Andrews Boston, Augt. 1810.

Wm W. Boardmans –
N. Haven Aug 181

AN

EPITOME

OF

EXPERIMENTAL CHEMISTRY,

IN THREE PARTS.

PART I.

INTENDED TO FACILITATE 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 METALLIC ORES; AND OF MINERAL BODIES
IN GENERAL. AND

PART III.

INSTRUCTIONS FOR APPLYING CHEMICAL TESTS AND RE-AGENTS
TO VARIOUS USEFUL PURPOSES.

BY WILLIAM HENRY, M. D.

Member of the Royal Medical and Nat. Hist. Societies of Edinb.; the Phys. Soc. of Jena;
the Brit. Min. Soc.; and Vice-President of the Lit. and Phil. Soc. of Manchester.

THE SECOND AMERICAN,

FROM THE FIFTH ENGLISH EDITION, ILLUSTRATED WITH PLATES.

TO WHICH ARE ADDED,

Notes on various subjects; Observations on Metals; Mines; Mining; Metallurgy; and on the
Artificial Preparation of Mineral Waters; an account of the New Discoveries of Professor Davy, and of the French Chemists; and of Meteoric Stones, &c.
With a Frontispiece, exhibiting the Pneumatic Cistern
of Yale College.

BY B. SILLIMAN,

Professor of Chemistry, &c. of Yale College.

BOSTON:
PUBLISHED BY WILLIAM ANDREWS No. 1. CORNHILL.
T. B. Wait and Co. Printers.
....
1810.

DISTRICT OF MASSACHUSETTS, TO WIT:

BE it remembered, That on the eleventh day of September, in the thirty-fifth year of the Independence of the United States of America, WILLIAM ANDREWS, of the said district, has deposited in this office the title of a book, the right whereof he claims as proprietor, in the words following, to wit:

"An Epitome of Experimental Chemistry, in three parts. Part I. Intended to facilitate the acquisition of chemical knowledge, by minute introductions for the performance of experiments. Part II. Directions for the analysis of mineral waters; of earths and stones; of metallic ores; and of mineral bodies in general. And Part III Introductions for applying chemical tests and re-agents to various useful purposes. By William Henry, M. D. Member of the Royal Medical and Nat. Hist. societies of Edinb.; the Phys. Soc. of Jena; the Brit. Min. Soc.; and Vice President. of the Lit. and Phil. Soc of Manchester. The second American, from the fifth English edition, illustrated with plates. To which are added, notes on various subjects, observations on metals; mines; mining; metallurgy; and on the artificial preparation of mineral waters; an account of the new discoveries of Professor Davy, and of the French chemists; and of meteoric stones, etc. with a frontispiece, exhibiting the pneumatic cistern of Yale College. By B. Silliman, Professor of Chemistry, etc. of Yale College.

In conformity to the Act of the Congress of the United States, intitled, "An Act for the encouragement of learning, by securing the copies of Maps, Charts, and Books, to the Authors and Proprietors of such copies, during the times therein mentioned;" and also to an act, intitled "An act supplementary to an act, intitled, an act for the encouragement of learning, by securing the copies of Maps, Charts, and Books, to the authors and proprietors of such copies during the times therein mentioned; and extending the benefits thereof to the Arts of Designing, Engraving, and Etching Historical, and other Prints."

WM. S. SHAW,

Clerk of the District of Massachusetts.

PREFACE

TO THE

FIFTH EDITION.

The Epitome of Chemistry, a new edition of which is now offered to the public, was originally compiled at a period, when we had not, in the English language, any elementary book on this science, of similar plan and intentions; and before I had seen the only work, which is at all coincident in design with my own, the "*Manuel d'un Cours de Chimie, par Bouillon La-Grange.*" The compendium of La-Grange, however, though containing a copious and well arranged collection of facts and processes, valuable even to the experienced chemist, appears to me to be adapted, rather to assist a public teacher in the practical execution of his office, than to direct an unskilled student to a train of simple and easy experiments. This object I have endeavoured to accomplish in the first part of the following work; which is to be considered as an assemblage of such facts, as are best adapted to convey a knowledge of the elements of the science, and by no means as a systematic arrangement of all that is known on the subject. With this view, I have described only the leading and characteristic properties of bodies; and have carefully avoided a multiplicity of details, because they would have encumbered the memory, and left to the reader that office of selection, which properly belongs to the author.

In the second part, which relates to the examination of mineral waters and of mineral bodies in general, I have collected, from various sources, the most simple and practicable methods of analysis. It is only, however, by an attentive perusal of the memoirs of Hatchett, Klaproth, Vauquelin, and other celebrated chemists, conjoined with actual experience, that facility or certainty, in the difficult art of analyzing minerals, can be acquired. And though general rules are, in this instance, of considerable utility, yet it is impossible to frame any, that can be adapted to the infinite variety, which nature presents, in the productions of the mineral kingdom.

Respecting the work in its present enlarged form, it is expedient to state, that in order to keep pace with the rapid progress of chemical science, it has been, almost entirely, written anew; and that what has been added to this and the preceding edition exceeds very considerably the original matter. In the Appendix will be found a variety of useful tables, partly original, but chiefly selected. The plates, exhibit, I believe, every article of apparatus, that is essential to the pursuit of operative chemistry. The sketches * have been made, from actual models, in the orthographic manner, which appears to me to possess, for this purpose, several advantages over the common mode of drawing in perspective; and is almost universally adopted in the recent works of the French chemists. It displays, with great distinctness, the most minute parts of complicated instruments; and being executed to a scale, which is placed at the bottom of each plate, a workman is enabled to construct what is represented, much more easily and accurately, than from any verbal description or perspective figure. The orthographic drawing has the recommendation, also, of greater facility; and of being less costly in the engraving.

MANCHESTER, January, 1808.

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* For these sketches I am indebted to my friends, Mr. Ewart, of Manchester; and Messrs. Creighton, of Soho, Birmingham.

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PART III.

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FRENCH EXPERIMENTS.

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 merely a history of the science, that is, a view of the progressive 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 a period, when the student may be supposed to be ignorant of the external forms, and even of the existence, of no inconsiderable part of them. Respecting chemists themselves, little can be said 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 which 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 subjects, which, requiring not the aid of an appeal to the senses, are equally well adapted for private study.

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* The following discourse formed, originally, the introduction to 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 to whom it was originally addressed.

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 connexion 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 philospher, produce, at most, only a change of place in the bodies that obey their influence. But, in chemical changes, we may always observe an important difference in the properties of things: Their appearances and qualities are completely altered, and their individuality destroyed. Thus, 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 complexion; 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 changes of composition that occur among the integrant and constituent parts of different 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 ena-

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* The reader, who wishes to examine other definitions of chemistry, will find a variety of them, collected by Dr. Black, in the first volume of his "Lectures."

bled to separate them with accuracy, and to allot to the sciences of natural philosophy 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 inferior to 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.

It has not been unusual to consider chemistry, under the two-fold view of a science and of an art. This arrangement, however, appears to have had its origin in an imperfect discrimination between two objects, that are essentially distinct. Science consists of assemblages of facts, associated together in classes, according to circumstances of resemblance or analogy. The business of its cultivators is, first, to investigate and establish individual truths, either by the careful observation of natural appearances, or of new and artificial combinations of phenomena produced by the instruments of experiment. The next step is the induction, from well ascertained facts, of general principles or laws, more or less comprehensive in their extent, and serving, like the classes and orders of natural history, the purposes of an artificial arrangement. Of such a body of facts and doctrines, the science of chemistry is composed. But the employment of the artist consists merely in producing a given effect, for the most part by the sole guidance of practice or experience. In the repetition of processes, he has only to follow an established rule; and, in the improvement of his art, he is benefitted generally by fortuitous combinations, to which he has not been directed by any general axiom. An artist, indeed, of enlarged and enlightened mind, may avail himself of general principles, and may employ them as an useful instrument in perfecting established operations: but the art and the science are still marked by a distinct boundary. In such hands, they are auxiliaries to each other; the one contributing a valuable accession of facts; and the other, in return, imparting fixed and comprehensive principles, which simplify the processes of art, and direct to new and important practices.

The possession of the general principles of chemistry enables us to comprehend the mutual relation of a great variety of events, that form a part of the established course of nature. It unfolds the most sublime views of the beauty and harmony of the universe; and developes a plan of vast extent, and of uninterrupted order, which could have been conceived only by perfect wisdom, and executed by unbounded power. By withdrawing the mind, also, from pursuits and amusements that excite the imagination, its investigations may tend, in common with the rest of the physical sciences, to the improvement of our intellectual and moral habits; to strengthen the faculty of patient and accurate thinking; and to substitute placid trains of feeling, for those which are too apt to be awakened by the contending interests of men in society, or the imperfect government of our own passions.

The class of natural events, that call for the explanations of chemical science, is of very considerable extent; and the natural philosopher (using this term in its common acceptation) is wholly incompetent to unfold their connexion. 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 caloric and light derived from the sun; the absorption of caloric 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 interest us even more nearly; because, though not more connected with our existence or comfort, yet they are more within our sphere of observation; and an acquaintance with their laws admits of a more direct application to human affairs.

There is another branch of knowledge (that of natural history), which is materially advanced by the application of chemical science. The classifications of the naturalist are derived from an examination and comparison of the external forms, both of animate and inanimate bodies. He distributes the whole range of nature into three great and comprehensive kingdoms,—the animal, the vegetable, and the mineral. Each of these, again, is subdivided into several less extensive classes; and individual objects are referred to their place in the system, by the agreement of their characters, with those assigned to the class, order, and genus. In the different departments of natural history, these resemblances vary in distinctness, in facility of observation, and in certainty of description. Thus, the number and disposition of the parts of fructification in vegetables afford marks of discrimination, which are well defined, and easily ascertained. But minerals, that are not possessed of a regularly crystallized form, are distinguished by outward qualities that scarcely admit of being accurately conveyed by language; such as minute shades of colour; or trifling differences of hardness, transparency, &c. To the evidence of these loose and varying characters, that of the chemical composition of minerals has within the few past years been added; and mineralogy has been advanced, from a confused assemblage of its objects, to the dignity of a well methodized and scientific system. In the example of crystallized bodies, the correspondence between external form and chemical composition, has been most successfully traced by the genius of Hauy; whose method of investigation has enabled him, in numerous instances, to anticipate, from physical characters, the results of the most skilful and laborious analysis.

It is unnecessary to pursue this part of the subject to a greater extent; because, to all who have been in the habit of philosophical investigation, the connexion between the sciences must be sufficiently apparent; and because there is another ground, on which chemistry is more likely to claim, with success, the respect and attention of the great mass of mankind. This is, its capacity of ministering to our wants and luxuries, and of instructing us to convert to the ordinary purposes of life, many substances which nature presents 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 dyeing 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 extremely degraded; and that they are the daily 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 for any one to frame rules for the practice of a chemical art, or to profit by the rules of others, who is unacquainted 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 ensure 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, 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.

It will scarcely be contended, that any one of the arts 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 any general 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 may have acted agreeably to established rules, and have 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 accidental difference, contributes at once to the promotion of his own interest, and to the advancement of his art.

But it is the union of theory with practice that is now recommended. 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 the latter*." "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 to artists, of the acquirement of scientific knowledge, is happily sanctioned by the illustrious success, in our own 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. Wedgewood; 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 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 acmé of perfection. Mr. Wedgewood, aided by the possession of extensive chemical knowledge, made rapid advances in the improvement of the art of manufacturing porcelain; and, besides raising himself to great opulence and distinction, has created for his 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 oxygenized 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

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* Stewart's Elements of the Philosophy of the Human Mind, chap. iv. sect. 7.

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 unerring certainty, that the same success will attend one on a greatly enlarged plan; because 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 alkali 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 immense 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 which we are entitled to expect, from the efforts of the artist and the man of science, united in one person, 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 more certain ground of superiority in the productions of its arts. Impressed with a full conviction of this influence of the sciences, a neighbouring and rival nation offer the most public and respectful incitements to the application of theory in the improvement of the chemical arts; and, with a 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, during a long war, supplied, from her own native resources, her enormous, and, perhaps, unequalled consumption of nitre. [See Note 1.]

The general uses of chemistry have been thus fully enlarged upon, because it is a conviction of the utility of the science, that alone can 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, the 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 so confused an 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 ages and nations. 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 characterized, 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 two thousand years. "To refute this assertion," says Mr. Kirwan, "we need only compare the writings of Cato, Columella, or Pliny, with many modern tracts, or, still better, with the modern practice of our best farmers."—"If the exact connexion 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 alone can 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 exemplified 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

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[*] See Kirwan on Manures.

a laboratory, in which are constantly going forward 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 must be acknowledged, however, as has been observed by Mr. Davy*, that "the connexion of chemistry with physiology has given rise to some visionary and seductive theories; yet even this circumstance has been useful to the public mind, in exciting it by doubt, and in leading it to new investigations. A reproach, to a certain degree just, has been thrown upon those doctrines known by the name of the chemical physiology; for, in the applications of them, speculative philosophers have been guided rather by the analogies of words than of facts. Instead of endeavouring slowly to lift up the veil, which conceals the wonderful phenomena of living nature; full of ardent imaginations, they have vainly and presumptuously attempted to tear it asunder."

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 connexion. But they appear thus disunited, 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 applica-

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* In his excellent "Discourse, Introductory to a Course of Lectures, &c. London. Johnson. 1802."

tion 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 art 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 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. Among these, the most conspicuous are, sugar in all its various forms; the vegetable and mineral alkalies, known in commerce by the names of potash, pearl-ash, 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 most instances to the success of the fermentative change. To acquire a precise acquaintance with the circumstances, that favour or retard the process of fermentation, no small share of chemical knowledge is required. The brewer should be able to ascertain, and to 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 truth, 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 the 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 particular facts, by diligently possessing 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 among 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 acquisition, he will yet be better fitted by it for conducting common operations, with certain and unvaried success.

6th. The *tanning and preparation of leather* are processes strictly chemical, which were involved in mystery, till they were reduced to well established principles, by the researches of Seguin, and by the subsequent experiments of Davy. In this, as in most other examples, the application of science to the practical improvement of an art, has to encounter the obstacles of ignorance and prejudice. But the interests of men are sure finally to prevail; and the most bigotted attachment to established forms must give place to the clearly demonstrated utility of new practices. Such a demonstration is generally furnished, by some artist of more enlightened views than his neighbours, who has the spirit to deviate from ordinary rules; and thus becomes (not unfrequently with some personal sacrifice) a model for the imitation of others, and an important benefactor of mankind.

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

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, which is ill suited to the plan of elementary instruction. 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.

To construct a classification of chemical facts, at once adapted to lead the student, by easy and certain steps, to a knowledge of the science, and at the same time conformable to the strict rules of philosophical arrangement, is attended with considerable difficulty. For since the phenomena of chemistry consist in the mutual action of a great variety of bodies on each other, it is impossible to enumerate the properties of any one substance, which may be selected as the first object of description, without tracing the agency of many other bodies upon it, which must necessarily, at the out-set, be unknown to the student. The action of certain bodies, however, is much more general and extensive than that of others. There are few chemical changes, for example, in which a combination or transfer of oxygen does not take place ; and the phenomenon is even so general, as to constitute the basis of a very comprehensive division into combustible and incombustible bodies. Still more extensive is the influence of affinity, and of caloric, over chemical changes ; and it is scarcely possible to describe any one of these changes, without using language connected with the peculiar doctrines respecting affinity.

Attraction, or affinity, therefore, as the great cause of all chemical phenomena, has 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 which 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 mechanical properties, with the air of our atmosphere, and called airs or gases. These gases, 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 gases, usually called their bases combine together, or with other bodies, caloric is given out, and new compounds are formed. And as the gaseous bases are, generally speaking, simple or elementary substances, the consideration of the gases, at an early period, 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 review, that are formed by the action of the gaseous bases on each other, such as water and ammonia. With ammonia, the two fixed alkalies are, by a natural order, associated; and an analogous genus of bodies, the earths, cannot, without confusion, be referred to a different place in the system. We shall then be prepared to understand the most remarkable qualities of various other combustible bodies, which qualities appear generally in their action on the gases. Thus, for example, the most remarkable property of sulphur, is its forming, with the basis of oxygen 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, and their effects will be 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, the alkalies, and the earths, only will be then described; for, it would be unseasonable to detail its effects on metallic 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 acids thus generated; and of the compounds afforded by the union of acids with alkalies, an important division of elementary substances will next claim our attention, viz. the metals.

This class of bodies, it is usual to introduce at a much earlier period: but I have adopted a different order, from the consideration, that with the previous knowledge of the constitution and qualities of acids, the history of the metals may be made much more complete; and, especially, that all the various modes and phenomena of their combinations with oxygen may be more distinctly explained. The more complex productions of the vegetable and animal kingdoms will be the last step in our progress through the science.

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 advocates of phlogiston. 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 connexion 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 acknowledged, 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.

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* See also Condorcet's "*Esquisse d'un Tableau Historique des Progres de l'Esprit Humain.*"

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. The catalogue of a complete chemical library would have occupied too much room, and perhaps would not have been of much utility.

Lavoisier's Elements of Chemistry, 8vo.

Works, from the French, by Henry, 1 vol. 8vo. and a pamphlet.

Nicholson's First Principles of Chemistry, 8vo.

Chemical Dictionary, 1 vol. 8vo.

Gren's Principles of Chemistry, 2 vols. 8vo.

La Grange's Manual of Chemistry, 2 vols. 8vo.

Pearson's Chemical Nomenclature, second edition, 4to.

Parkinson's Chemical Pocket-book, 4th edition.

Nicholson's Philosophical Journal, published monthly.

Philosophical Magazine, published monthly.

A System of Chemistry, by Thomas Thomson, M. D. 5 vols. 8vo.

A System of Chemistry, by J. Murray, 4 vols. 8vo.

Remarks on Chemical Nomenclature, by R. Chenevix, Esq. F. R. S. &c.

Dr. Black's Lectures on the Elements of Chemistry, 2 vols. 4to.

Accum's System of Chemistry, 2 vols. 8vo.

Fourcroy's System of Chemical Knowledge, 10 vols. 8vo.

Aikins' Dictionary of Chemistry, Mineralogy, and the Chemical Arts, 2 vols. 4to.

Joyce's Chemical Dialogues, for the Use of Young Persons, 2 vols. 12mo. with plates.

AN

EPITOME

OF

EXPERIMENTAL CHEMISTRY.

PART I.

AN ARRANGED SERIES OF EXPERIMENTS AND PROCESSES TO BE PERFORMED BY THE STUDENT OF CHEMISTRY.

CHAPTER I.

PRELIMINARY OBSERVATIONS.

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 their own experiments.

One of the principal difficulties, experienced by all who embark in a scientific pursuit, unaided by personal instruction, 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 afterwards 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 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 avail himself of other elementary books, especially those of Murray, and Thomson*. These works will supply the deficiencies of Lavoisier's Elements, especially on the subject of chemical affinity, the principal laws of which are essential to be known, as the ground work of all chemical explanations. The doctrine respecting caloric, the most important and extensive of all chemical agents, is developed, with admirable perspicuity, though perhaps not with strict conformity to theoretical truth, in the first volume of Dr. Black's lectures. After having made himself master of the more general truths of chemistry, and also of the principles of the new nomenclature, as explained by Lavoisier, 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 Murray, or Thomson, referring to the following pages 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 phial, have a label affixed to it, denoting the substances which it may contain (except in cases where the 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 relate which, with selection and precision, is far from being a universal talent.

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* Dr. Thomson's excellent "System of Chemistry" is the work to which I refer. See the list of Elementary Books at the end, where the title of Mr. Murray's new and enlarged work is also given.

SECTION II.

Of a Chemical Laboratory and Apparatus.

A chemical laboratory, though extremely useful, and even essential, to all who embark extensively in the practice of chemistry, either as an art, or as a branch of liberal knowledge, is by no means required for the performance of those simple experiments, which furnish the evidence of the fundamental truths of the science. A room that is well lighted, easily ventilated, and destitute of any valuable furniture, is all that is absolutely necessary for the purpose. It is even advisable, that the construction of a regular laboratory should be deferred, till the student has made some progress in the science; for he will then be better qualified to accommodate its plan to his own peculiar views and convenience.

It is scarcely possible to offer the plan of a laboratory, which will be suitable to every person, and to all situations; or to suggest any thing more than a few rules that should be generally observed. Different apartments are required for the various classes of chemical operations. The principal one may be on the ground floor; twenty-five feet long, fourteen or sixteen wide, and open to the roof, in which there should be contrivances for allowing the occasional escape of suffocating vapours. This will be destined chiefly for containing furnaces, both fixed and portable. It should be amply furnished with shelves and drawers, and with a large table in the centre, the best form of which is that of a double cross. Another apartment may be appropiated to the minuter operations of chemistry; such as those of precipitation on a small scale, the processes that require merely the heat of a lamp, and experiments on the gases. In a third, of smaller size, may be deposited accurate balances, and other instruments of considerable nicety, which would be injured by the acid fumes that are constantly spread through a laboratory.

The following are the principal instruments that are required in chemical investigations; but it is impossible, without entering into very tedious details, to enumerate all the apparatus that should be in the possession of a practical chemist.

I. Furnaces. [See note 2.] These may either be formed of solid brick-work, or of such materials as admit of their removal from place to place.

The directions generally laid down in elementary books of chemistry, for the construction of fixed furnaces, appear to me deficient in precision, and such as a workman would find it difficult to put in practice. I have, therefore, given plans and sections, in the last two plates, of the various kinds of furnaces; and, in the appendix, minute instructions will be found for erecting them.*

The furnaces of most general utility are, 1st, the *Wind Furnace*, in which an intense heat is capable of being excited for the fusion of metals, &c. In this furnace, the body submitted to the action of heat, or the vessel containing it, is placed in contact with the burning fuel. Fig. 60. exhibits one of the most common construction. Fig. 61. is the section of a wind furnace; the plan of which was obligingly communicated to me by Mr. Knight, of Foster-lane, London, to whom, also, I am indebted for that represented, fig. 62. The wind furnace of Mr. Chenevix is shown by fig. 74. 2dly, The *Evaporating Furnace* is formed of iron plates, joined together by rabbiting, and placed over horizontal returning flues. Figs. 64. and 65. are two views of this furnace, as recommended by Mr. Knight. When evaporation is performed by the naked fire, the vessel may be placed on the top of the furnace, fig. 60. or 61.; and when effected through the intervention of a water bath, a shallow kettle of water, in which is placed the evaporating dish and its contents, may be set in the same situation. For the purposes of evaporating liquids, and drying precipitates on a small scale, at a temperature not exceeding 212° Fahrenheit, a convenient apparatus is represented in plate 10th to the 6th vol. of Nicholson's Journal, 8vo. 3dly, The *Reverberatory Furnace* is represented by figs. 66, 67, 68. 4thly, *The Furnace for Distilling by a Sand Heat*, is constructed, by setting upon the top of the brick-work, fig. 60, the iron pot, fig. 71.; a door being made in the side of the furnace for introducing fuel. Distillation by the naked fire, is performed with the wind furnace, figs. 62, 63. 5thly, The *Cupelling, or Enamelling Furnace*, is shown by figs. 69, 70.

Portable furnaces, however, are amply sufficient for all the purposes of the chemical student, at the outset of his pursuit. The one which I prefer is that shown by figs. 58. and 59. It was originally contrived, I believe, by Mr. Schmeisser†; and is made, with considerable improvements, and sold by Mr. Knight. Its size is so small, that it may be set on a table, and the smoke may be conveyed by a crooked iron pipe, into the chimney of the

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* See the Description of the Plates.

† See his Mineralogy, Tab. iii. and iv.

apartment. Dr. Black's furnace is generally made of a larger size; and is adapted to operations on a more considerable scale. (See figs. 72. and 73.) Both these furnaces are constructed of thin iron plates, and are lined with fire-clay. They will be minutely described in the references to the plates.

For the purpose of exciting a sudden heat, and of raising it to great intensity, nothing can be better adapted than a very simple, cheap, and ingenious furnace, contrived by Mr. Charles Aikin, fig. 55. It is formed out of pieces of black lead melting pots, in a manner to be afterwards described; and is supplied with air by a pair of double bellows, *d*. By a slight alteration, this furnace may occasionally be employed for the operation of cupelling. (See fig. 57.)

II. For containing the materials, which are to be submitted to the action of heat in a wind furnace, vessels called CRUCIBLES are employed. They are most commonly made of a mixture of fire-clay and sand, occasionally with the addition of plumbago, or black-lead. The Hessian crucibles are best adapted for supporting an intense heat without melting; but they are liable to crack when suddenly heated or cooled. The procelain ones, made by Messrs. Wedgewood, are of much purer materials, but are still more apt to crack on sudden changes of temperature; and, when used, they should, therefore, be placed in a common crucible of larger size, the interval being filled with sand. The black-lead crucibles resist very sudden changes of temperature, and may be repeatedly used; but they are destroyed when some saline substances (such as nitre) are melted in them, and are consumed by a current of air. For certain purposes crucibles are formed of pure silver, or platina. Their form varies considerably, as will appear from inspecting figs. 49, 50, 51, and 54. It is necessary, in all cases, to raise them from the bars of the grate, by a stand, fig. 53, *a* or *b*. For the purpose of submitting substances to the continued action of a red heat, and with a considerable surface exposed to the air, the hollow arched vessel, with a flat bottom, fig. 52. termed a *muffle*, is commonly used. In fig. 69. *d*, *e*, the muffle is shown, placed in a furnace for use.

III. EVAPORATING VESSELS should always be of a flat shape, so as to expose them extensively to the action of heat. (See a section of one, fig. 12.) They are formed of glass, of earthen ware, and of various metals. Those of glass are with difficulty made sufficiently thin, and are often broken by changes of temperature; but they have a great advantage in the smoothness of their surface, and in resisting the action of most acid and corrosive substances. Evaporating vessels [See Note 3] of porcelain, or Wedgewood's ware, are next in utility, are less costly, and less liable to be cracked. They are made both of glazed and unglazed ware. For ordinary purposes the former are to be preferred ; but the unglazed should be employed when great accuracy is required, since the glazing is acted on by several chemical substances. Evaporating vessels of glass, or porcelain, are generally bedded, up to their edge, in sand, (see fig. 65.) ; but those of various metals are placed immediately over the naked fire. When the glass or procelain vessel is very thin, and of small size, it may be safely placed on the ring of the brass stand, plate i. fig. 13., and the flame of an Argand's lamp, cautiously regulated, may be applied beneath it. A lamp thus supported, so as to be raised or lowered, at pleasure, on an upright pillar, to which rings, of various diameters, are adapted, will be found extremely useful ; and, when a strong heat is required, it is advisable to employ a lamp, provided with double concentric wicks.

IV. In the process of evaporation, the vapour for the most part is allowed to escape ; but of certain chemical processes, the collection of the volatile portion is the principal object. This process is termed, DISTILLATION. It is performed in vessels of various forms and materials. The common still is so generally known, that a representation of it in the plates was deemed unnecessary. (See Aikin's Chem. Dict. pl. ii. fig. 31.) It consists of a vessel, generally of copper, shaped like a tea-kettle, but without its spout and handle. Into the opening of this vessel, instead of a common lid, a hollow moveable head is affixed, which ends in a narrow, open pipe. This pipe is received into another tube of lead, which is twisted spirally, and fixed in a wooden tub, so that it may be surrounded by cold water. (Fig. 40. *dd.*) When the apparatus is to be used, the liquid intended to be distilled is poured into the body of the still, and the head is fixed in its place, the pipe, which terminates it, being received into the leaden worm. The liquid is raised into vapour, which passes into the worm, is there condensed by the surrounding cold water, and flows out at the lower extremity.

The common still, however, can only be employed for volatilizing substances that do not act on copper, or other metals, and is, therefore, limited to very few operations. The vessel, fig. 2., is of glass, or earthen ware, and is also intended for distillation. It is termed an *alembic*, and consists of two parts ; the body *a* for containing the materials, and the head *b* by which the vapour is condensed; the pipe *c* conveying it to a receiver. Vessels, termed *retorts*, however, are more generally used. Fig. 1. *a* shows the common form, and fig. 13. *a* represents a stoppered, or tubulated retort. Retorts are made of glass, of earthen ware, or of metal. When a liquid is to be added at distant intervals during the process, the best contrivance is that shown fig. 26. *a*, consisting of a bent tube, with a funnel at the upper end. When the whole is introduced at first, it is done either through the tubulure, or, if into a plain retort, through the funnel, fig. 10.

To the retort, a *receiver* is a necessary appendage; and this may either be plain, fig. 1. *b*, or tubulated, as shown by the dotted lines at *c*. To some receivers a pipe is added (fig. 13. *b*), which may enter partly into a bottle beneath. This vessel, which is principally useful for enabling us to remove the distilled liquid, at different periods of the process, is termed a *quilled receiver*. For some purposes, it is expedient to have the quilled part accurately ground to the neck of the bottle, *c*, which should then be furnished with a tubulure, or second neck, having a ground stopper, and should be provided, also, with a bent tube, to be occasionally applied, for conveying away any gases that may be produced. The condensation of the vapour is much facilitated, by lengthening the neck of the retort with an *adopter* (fig. 11.), the wider end of which slips over the retort neck, while its narrow extremity is admitted into the mouth of the receiver. (See fig. 63.)

Heat may be applied to the retort in several modes. When the vessel is of earthen ware, and when the distilled substance requires a strong heat to raise it into vapour, the naked fire is applied, as shown fig. 63. Glass retorts are generally placed in heated sand (fig. 59.); and, when of a small size, the flame of an Argand's lamp, cautiously regulated, may be conveniently used (fig. 13.).

In several instances, the substance raised by distillation is partly a condensable liquid, and partly a gas, which is not condensed till it is brought into contact with water. To effect this double purpose, a series of receivers, termed *Woulfe's Apparatus*, is employed. The first receiver (*b*, fig. 30.) has a right-angled glass tube, open at both ends, fixed into its tubulure; and the other extremity of the tube is made to terminate beneath the surface of distilled water, contained, as high as the horizontal dotted line, in the three-necked bottle *c*. From another neck of this bottle, a second pipe proceeds, which ends, like the first, under water, contained in a second bottle *d*. To the central neck a straight tube, open at both ends, is fixed, so that its lower end may be a little beneath the surface of the liquid. Of these bottles any number may be employed that is thought necessary.

The materials being introduced into the retort, the arrangement completed, and the joints secured in the manner to be presently described, the distillation is begun. The condensable vapour collects in a liquid form in the balloon *b*, while the evolved gas passes through the bent pipe, beneath the surface of the water in *c*, which continues to absorb it till saturated. When the water of the first bottle can absorb no more, the gas passes, uncondensed, through the second right-angled tube, into the water of the second bottle, which, in its turn, becomes saturated. Any gas that may be produced, which is not absorbable by water, escapes through the bent tube *e*, and may be collected, if necessary.

Supposing the bottles to be destitute of the middle necks, and, consequently, without the perpendicular tubes, the process would be liable to be interrupted by an accident: for if, in consequence of a diminished temperature, an absorption of condensation of gas should take place, in the retort *a*, and, of course, in the balloon *b*, it must necessarily ensue that the water of the bottles *c* and *d* would be forced, by the pressure of the atmosphere, into the balloon, and possibly into the retort; but, with the addition of the central tubes, a sufficient quantity of air rushes through them to supply any accidental vacuum. This inconvenience, however, is still more conveniently obviated by Welther's tube of safety (fig. 31. *b*), which supersedes the expediency of three-necked bottles. The apparatus being adjusted, as shown by the figure, a small quantity of water is poured into the funnel, so as to about half fill the ball *b*. When any absorption happens, the fluid rises in the ball, till none remains in the tube, when a quantity of air immediately rushes in. On the other hand, no gas can escape, because any pressure from within is instantly followed by the formation of a high column of liquid in the perpendicular part, which resists the egress of gas. This ingenious invention I can recommend, from ample experience of its utility.

Very useful alterations in the construction of Woulfe's apparatus have been contrived also by Mr. Pepys and Mr. Knight. That of the former is shown (fig. 32.), where the balloon *b* is surmounted by a vessel accurately ground to it, and furnished with a glass valve, resembling that affixed to Nooth's apparatus. This valve allows gas to pass freely into the vessel *c*, but prevents the water which it contains from falling into the balloon. Mr. Knight's improvement is described, and represented in a plate, in the Philosophical Magazine, vol. xx.*

When a volatile substance is submitted to distillation, it is necessary to prevent the escape of the vapour through the junctures of the vessels; and this is accomplished by the application of LUTES. [See note 4.] The most simple method of confining the vapour, it is obvious, would be to connect the places of juncture accurately together by grinding; and accordingly the neck of the retort is sometimes ground to the mouth of the receiver. This, however, adds too much to the expense of apparatus to be generally practised.

When the distilled liquid has no corrosive property (such as water, alcohol, ether, &c.), slips of moistened bladder, or of paper, or linen, spread with flour paste, white of egg, or mucilage of gum arabic, sufficiently answer the purpose. The substance which remains, after expressing the oil from bitter almonds, and which is sold under the name of almond-meal, or flour, forms a useful lute, when mixed, to the consistency of glazier's putty, with water or mucilage. For confining the vapour of acid, or highly corrosive substances, the fat lute is well adapted. It is formed by beating perfectly dry and finely sifted tobacco pipe-clay, with painters' drying oil, to such a consistence that it may be moulded by the hand. The same clay, beat up with as much sand as it will bear, without losing its tenacity, with the addition of cut tow, or of horse-dung, and a proper quanity of water, furnishes a good lute, which has the advantage of resisting a considerable heat, and is applicable in cases where the fat lute would be melted or destroyed. Various other lutes are recommended by chemical writers; but the few that have been enumerated I find to be amply sufficient for every purpose.

On some occasions, it is necessary to protect the retort from too sudden changes of temperature, by a proper coating. For

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* Another modification of this apparatus, by Mr. Murray, is represented in Nich. Journ. 8vo. vol. iii. or in Murray's System of Chemistry, vol. i. plate v. fig. 40. Fig. 41. of the same plate exhibits a cheap and simple form of this apparatus, contrived by the late Dr Hamilton, and depicted originally in his translation of Berthollet on Dyeing. Mr. Burkitt's improvement of this apparatus may be seen in Nicholson's Journal, 4to. vol. v. 349.

glass retorts, a mixture of common clay, or loam, with sand, and cut shreds of flax, may be employed. If the distillation be performed by a sand heat, the coating needs not to be applied higher than that part of the retort which is bedded in sand; but if the process be performed in a wind furnace (fig. 63.), the whole body of the retort, and that part of the neck also which is exposed to heat, must be carefully coated. To this kind of distillation, however, earthen retorts are better adapted; and they may be covered with a composition originally recommended by Mr. Willis. Two ounces of borax are to be dissolved in a pint of boiling water, and a sufficient quantity of slaked lime added, to give it the thickness of cream. This is to be applied by a painter's brush, and allowed to dry. Over this a thin paste is afterwards to be applied, formed of slaked lime and common linseed-oil, well mixed and perfectly plastic. In a day or two, the coating will be sufficiently dry to allow the use of the retort.

For joining together the parts of iron vessels, used in distillation, a mixture of the finest China clay, with solution of borax, is well adapted. In all cases, the different parts of any apparatus made of iron should be accurately fitted by boring and grinding, and the above lute is to be applied to the part which is received into an aperture. This will generally be sufficient without any exterior luting; otherwise the lute of clay, sand, and flax, already described, may be used.

In every instance, where a lute or coating is applied, it is adviseable to allow it to dry before the distillation is begun; and even the fat lute, by exposure to the air during one or two days after its application, is much improved in its quality. The clay and sand lute is perfectly useless, except it be previously quite dry. In applying a lute, the part immediately over the juncture should swell outwards, and its diameter should be gradually diminished on each side. (See fig. 13., where the luting is shown, applied to the joining of the retort and receiver.)

Besides the apparatus already described, a variety of vessels and instruments are necessary, having little resemblance to each other, in the purposes to which they are adapted. Glass vessels are required for effecting *solution*, which often requires the application of heat, and sometimes for a considerable duration. In the latter case, it is termed digestion, and the vessel, fig. 4., called a *mattras*, is the most proper for performing it. When solution is quickly effected, the bottle, fig. 5., with a rounded bottom, may be used; or a common Florence oil flask serves the same purpose extremely well, and bears, without cracking, sudden changes of temperature. For *precipitations*, and separating liquids from precipitates, the decanting-jar (fig. 16.) will be found useful; or, if preferred, it may be shaped as in fig. 26. *f*. Liquids, of different specific gravities, are separated by the vessel fig. 3.; the heavier fluid being drawn off through the cock *b*, and air being admitted by the removal of the stopper *a*, to supply its place. Glass rods, of various length, and spoons of the same material, or of porcelain, are useful for stirring acid and corrosive liquids; and a stock of cylindrical tubes, of various sizes, is required for occasional purposes. It is necessary also to be provided with a series of glass measures, graduated into drachms, ounces, and pints.

Accurate beams and scales, of various sizes, with corresponding weights, some of which are capable of weighing several pounds, while the smaller size ascertains a minute fraction of a grain, are essential instruments in the chemical laboratory. So also are mortars of different materials, such as of glass, porcelain, agate, and metal. Wooden stands, of various kinds, for supporting receivers, should be provided. (See Aikin's Chem. Dict. pl. iv. fig. 59. *e*.) For purposes of this sort, and for occasionally raising to a proper height any article of apparatus, a series of blocks, made of well seasoned wood, eight inches (or any other number) square, and respectively eight, four, two, one, and half an inch in thickness, will be found extremely useful; since, by combining them in different ways, thirty-one different heights may be obtained.

The blow-pipe [see Note 5.] is an instrument of much utility in chemical researches. A small one, invented by Mr. Pepys, with a flat cylindrical box for condensing the vapour of the breath, and for containing caps, to be occasionally applied with apertures of various sizes, is perhaps the most commodious form. (See Aikin's Chem. Dict. pl. vii. fig. 71, 72, 73.) A blow-pipe, which is supplied with air from a pair of double bellows worked by the foot, may be applied to purposes that require both hands to be left at liberty, and will be found useful in blowing glass, and in bending tubes. [See Note 6.] The latter purpose, however, may be accomplished by holding them over an Argand's lamp with double wicks.

In the course of this work, various other articles of apparatus will be enumerated, in detailing the purposes to which they are adapted, and the principles on which they are constructed. It must be remembered, however, that it is no part of my object to describe every ingenious and complicated invention, which has been employed in the investigation of chemical science; but merely to assist the student in attaining apparatus for general and ordinary purposes. For such purposes, and even for the prosecution of new and important inquiries, very simple means are sufficient; and some of the most interesting chemical facts may be exhibited with the aid merely of Florence flasks, of common vials, and of wine glasses. In converting these to the purposes of apparatus, a considerable saving of expense will accrue to the experimentalist; and he will avoid the encumbrance of various instruments, the value of which consists in show, rather than in real utility.

In the selection of 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.

CHAPTER II.

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.

I. *Some bodies have no affinity for each other.*—Oil and water, mercury and water, or powdered chalk and water, when shaken together in a vial, do not combine, the oil or water always rising to the surface, and the mercury or chalk sinking to the bottom.

II. *Examples of chemical affinity, and its most simple effect, viz. solution.*—Sugar or common salt disappears or dissolves in water; chalk in dilute muriatic acid*. Sugar and salt are, there-

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

fore, said to be *soluble* in water, and chalk in muriatic acid. The liquid in which the solid disappears, is termed a *solvent*.

III. *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. Muriate of lime, or nitrate of ammonia, cast, after liquefaction by heat, into the shape of a solid sphere, is very slowly dissolved; but with great rapidity when in the state of a powder or of crystals. When a lump of the Derbyshire fluate of lime is immersed in concentrated sulphuric acid, scarcely any action of the two substances on each other takes place; but if the stone be finely pulverized, and then mingled with the acid, a violent action is manifested, by the copious escape of vapours of fluoric acid. In the common arts of life, the rasping and grinding of wood and other substances are familiar examples.

IV. *Hot liquids, generally speaking, 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 heat, and the whole of the salt will disappear. When the liquor cools, a portion of salt will separate again in a regular form or in *crystals*. This last appearance affords an instance of *crystallization*. [See Note 7.]

To this law, however, there are several exceptions; for many salts, among which is muriate of soda, or common salt, are equally, or nearly equally, soluble in cold as in hot water. (See the table of solubility of salts in water, in the Appendix.) Hence, a hot and saturated solution of muriate of soda does not, like the sulphate, deposit crystals on cooling. To obtain crystals of the muriate, and of other salts which observe a similar law as to solubility, it is necessary to evaporate a portion of the water; and the salt will then be deposited, even while the liquor remains hot. In general, the more slow the cooling, or evaporation, of saline solutions, the larger and more regular are the crystals.

V. *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-glassful 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.

VI. *Some bodies dissolve much more readily and copiously than others.*—Thus, an ounce measure of distilled water will dissolve half its weight of sulphate of ammonia, 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.

VII. *Mechanical agitation facilitates solution.*—Into a wine-glassful of water, tinged blue with the infusion of litmus, let fall a small lump of solid tartaric 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.

VIII. *Bodies do not act on each other, unless either one or both be in a state of solution.*—1. Mix some dry tartaric or citric acid 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 alkali, as appears from a violent effervescence.

2. Spread thinly, on a piece of tinfoil, three or four inches square, some dry nitrate of copper*, [See Note 8.] and wrap it up. No effect will follow. Unfold the tinfoil, and having sprinkled the nitrate of copper with the smallest possible quantity of water, wrap the tinfoil 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, unless in a state of solution.

IX. *Bodies, even when in a state of solution, do not act on each other at perceptible distances;* in other words, contiguity is essential to the action of chemical affinity.—Thus, when two fluids of different specific gravities, and which have a strong affinity for each other, are separated by a thin stratum of a third, which exerts no remarkable action on either, no combination ensues between the uppermost and lowest stratum. Into a glass jar, or deep ale glass, pour two ounce-measures of a solution of carbonate of potash, containing, in that quantity, two drachms of common salt of tartar. Under this introduce, very carefully, half an ounce-measure of water, holding in solution a drachm of

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* 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 evoporate it to dryness, in a copper or earthen dish. The dry mass must be kept in a bottle.

common salt; and again, under both these, two ounce-measures of sulphuric acid, which has been diluted with an equal weight of water, and allowed to become cool. The introduction of a second and third liquid beneath the first, is best effected, by filling, with the liquid to be introduced, the dropping tube fig. 15. pl. i., which may be done by the action of the mouth. The finger is then pressed on the upper orifice of the tube; and the lower orifice, being brought to the bottom of the vessel containing the liquid, the finger is withdrawn, and the liquid descends from the tube, without mingling with the upper stratum. When a solution of carbonate of potash is thus separated from diluted sulphuric acid, for which it has a powerful affinity, by the intervention of a thin stratum of brine, the two fluids will remain distinct and inefficient on each other; but, on stirring the mixture, a violent effervescence ensues, in consequence of the action of the sulphuric acid on the potash.

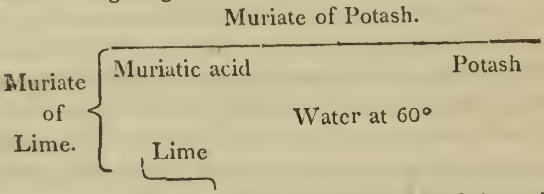
X. *Two bodies, having no affinity for each other, unite by the intervention of a third.*—Thus, the oil and water which, in Experiment I., could not, by agitation, be brought into union, unite immediately on adding a solution of caustic potash. The alkali, in this case, acts as an intermedium.

XI. *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 or neutralized.

XII. *Some bodies unite in one definite proportion only; others in two or three; while others again unite in all proportions.*—Thus azote and hydrogen are only known to combine in the proportion of 80 parts of the former to 20 of the latter. The tartaric acid affords two distinct compounds, with two different proportions of potash. Sulphuric acid unites with water, in almost every proportion.

XIII. *The properties characterizing bodies, when separate, are destroyed by chemical combination, and new properties appear in the compound.*—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 longer reddens syrup of violets; nor does the lime change it, as before, to green. The resulting compound, also, muriate of lime, exhibits new properties. It has an intensely bitter taste; is susceptible of a crystallized form; and the crystals, when mixed with snow or ice, generate a degree of cold sufficient to freeze quicksilver.

XIV. *Simple elective affinity illustrated.*—1. Add to the combination of oil with alkali, formed in Experiment X., a little diluted sulphuric acid. The acid will seize the alkali, and set the oil at liberty, which will rise to the top. In this instance, the affinity of alkali for acid is greater than that of alkali for oil. 2. To a dilute solution of muriate of lime (prepared in Experiment II.), 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.* The latter experiment may be illustrated by the following diagram:



The scheme implies, that the principles of the original compound, viz. lime and muriatic acid, are dis-united by the addition of potash, and that the new compound, muriate of potash, remains in solution. If the new salt had been precipitated, then, instead of the horizontal line, a bracket would have been placed, with its point turned downwards; if volatile, the point would have been directed upwards. The point of the half-bracket, beneath the word *lime*, being turned downward, shows also that the lime is precipitated. These schemes admit of a considerable variety of modifications, as the phenomena of decomposition vary.

From facts of this kind, tables of elective affinity have been formed. The substance, whose affinities are to be represented, is placed at the head of a column; and beneath it the bodies for which it has an attraction, placing those nearest to it which it attracts most strongly. Thus, in representing the affinities of muriatic acid, the following scheme is employed*:

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* See the Table of Affinities in the Appendix.

Muriatic Acid.

Barytes,
Potash,
Soda,
Strontites,
Lime,
Ammonia,
Magnesia,
Glucine,
Alumine,
&c. &c.

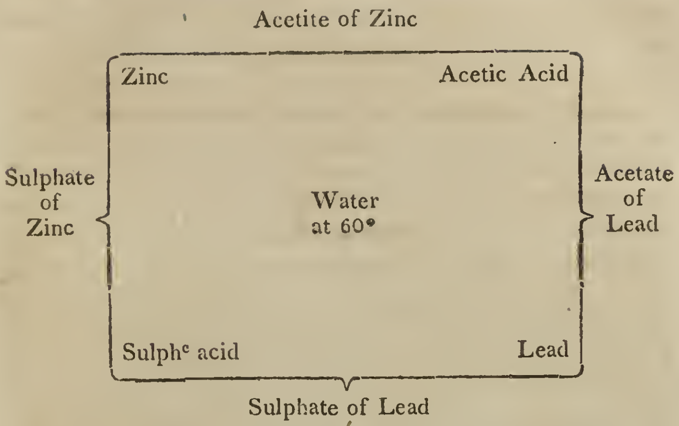
XV. *In every instance, in comparing the affinities of two bodies for a third, a weaker affinity, in one of the two compared, will be found to be compensated by increasing its quantity.*—Thus, though from a compound of A and C, B may be unable to detach any part of C, when employed only in the quantity which would be required to saturate C if separate; yet, by greatly augmenting its quantity, B acquires a portion of C, and partly decomposes the former compound. Barytes, for example, has a stronger affinity than potash for muriatic acid: but, if a combination of barytes and muriatic acid be boiled in contact with a large quantity of potash, the potash will detach muriatic acid from the barytes, in direct proportion to its quantity.

It is not easy to offer clear and unequivocal examples of this law, and such as the student may submit to the test of experiment. The following, however, may illustrate the proposition sufficiently: Mingle together, in a mortar, one part of muriate of soda (common salt) with half a part of red oxide of lead (litharge, or red-lead), and add sufficient water to form a thin paste. The oxide of lead, on examining the mixture after twenty-four hours, will be found not to have detached the muriatic acid from the soda; for the strong taste of that alkali will not be apparent. Increase the weight of the oxide of lead to three or four times that of the salt; and, after the same interval, the mixture will exhibit, by its taste, marks of uncombined soda. This proves, that the larger quantity of the oxide must have detached a considerable portion of muriatic acid from the soda, though the oxide has a weaker affinity for that acid than the soda possesses.

It is in consequence of the same law, that, if we take a given quantity of muriatic acid, and add to it, at the same time, a portion of barytes, and another of potash, either of which would have been precisely sufficient for saturating the acid, if separately applied, the whole of the barytes does not combine with the whole of the acid, to the complete exclusion of the potash; but the latter substance, also, combines with a portion of the acid. Hence muriate of barytes, and muriate of potash, are both formed, and a part of each base remains uncombined. According to Berthollet, the absolute weight of any body, multiplied by its affinity, constitutes its mass; and bodies act not by their affinities, abstractedly considered, but by their mass; a larger mass compensating a weaker affinity. Thus supposing, for the sake of illustration (what is not accurate in fact), that the affinity of barytes for muriatic acid is twice as strong as that of potash, or that these affinities are respectively denoted by the numbers 4 and 2, the same mass will result from 4 parts of barytes as from 8 of potash; because the same product (16) is obtained, in each instance. by multiplying the number indicating the affinity into that denoting the quantity: that is, 4 (the affinity of barytes) multiplied by 4 (the quantity assumed in this example) is equal to 16; and 2 (the affinity of potash) multiplied by 8 (its quantity) is also equal to 16. In this case, therefore, to divide equally a portion of muriatic acid, between barytes and potash, these two bodies should be employed in the proportion of 2 of the former to 4 of the latter.

The important influence of mass has been extensively traced by Berthollet, and has been applied by him to the explanation of a great variety of chemical phenomena. When the student has enlarged his acquaintance with this science, and has become familiar with its common facts, it will be expedient that he should read attentively the "Chemical Statics" of Berthollet, and his "Researches into the Laws of Affinity."

XVI. *Double elective affinity exemplified.*—In a watery solution of sulphate of zinc, immerse a thin sheet of lead: the lead will remain unaltered, as also will the sulphate of zinc, because zinc attracts sulphuric acid more strongly than lead. But let a solution of acetate of lead be mixed with one of sulphate of zinc: the lead will then go over to the sulphuric acid, while the zinc passes to the acetic. The sulphate of lead, being insoluble, will fall down in the state of a white powder; but the acetate 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 line and bracket point out the new ones, viz. acetite of zinc and sulphate of lead. By the upper horizontal line, it is denoted, that the acetite of zinc remains in solution; and, by the point of the lower bracket 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 horizontal line. If either of the new substances had escaped, in consequence of being volatile, then, for the simple straight line, a bracket would have been substituted with the point directed upwards.

The phenomena of double affinity have been shown by Berthollet, to be equally influenced by the circumstance of quantity, with those of single affinity. The experiments of this philosopher have proved, that a complete exchange of bases, which might have been expected from the enunciation of the general law, happens in very few instances. Numerous examples of these exceptions may be seen, p. 103. and 106. of his "Researches."

CHAPTER III.

EFFECTS AND ABSORPTION OF THE MATTER OF HEAT, OR CALORIC.

SECTION I.

Effects of Caloric.

I. *Caloric expands all bodies.*—1. The expansion of liquids is shown by that of the mercury of a thermometer, or by immersing in hot water a glass mattras (pl. i. fig. 4.), filled, up to a mark in the neck, with spirit of wine, tinged with any colouring substance. The spirit expands immediately when heated, and would overflow if not placed in a cooler situation. The degree of expansion produced in different liquids, by similar elevations of temperature, varies very considerably. Thus, water expands much more than mercury, and alcohol more than water. (See a table of the expansion of liquids, in the Appendix.) 2. The expansion of aeriform bodies is shown, by holding, near the fire, a bladder 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. All aeriform bodies undergo the same expansion by the same additions of heat, or $\frac{1}{483}$ part of their bulk for each degree of Fahrenheit's thermometer, between the freezing and boiling points. 3. The expansion of solids is evinced, 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 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.

The degree of expansion is not the same for all solids, and even differs materially in substances of the same class. Thus, the metals expand in the following order, the most expansible being placed first; zinc, lead, tin, copper, bismuth, iron, steel, antimony, palladium, platina. (See the Table.)

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

II. *Construction of the Thermometer founded on the principle of expansion.*—The thermometer is an instrument of so much importance, that it may be expedient to explain the construction of the different kinds which are required in chemical reseaches.

The instrument employed by Sanctorio, to whom the invention of the thermometer is generally ascribed, was of a very simple kind, and measured variations of temperature by the variable expansion of a confined portion of air. To prepare this instrument, a glass tube (pl. i. fig. 9.) is to be provided, eighteen inches long, open at one end, and blown into a ball at the other. On applying a warm hand to the ball, the included air expands, and a portion is expelled through the open end of the tube. In this state, the aperture is quickly immersed in a cup filled with any coloured liquid, which ascends into the tube, as the air in the ball contracts by cooling. The instrument is now prepared. An increase of temperature forces the liquor down the tube; and, on the contrary, the application of cold causes its ascent. These effects may be exhibited, by alternately applying the hand to the ball, and then blowing on it with a pair of bellows; and, by the application of a graduated scale, the amount of the expansion may be measured.

The ball of the above instrument, it must be obvious, cannot be conveniently applied to measure the temperature of liquids. To adapt it to this purpose, a slight variation may be made in its construction, as represented fig. 8. *a*. Other modifications have also been made by different philosophers. One of the most useful and simple forms is represented fig. 8. *b*. It consists merely of a tube of very small bore, from 9 to 12 inches long, at one end of which is blown a ball, from half an inch to an inch in diameter, which is afterwards blackened by paint, or by the smoke of a candle. A small column of coloured liquid, about an inch in length, is then introduced, by a manipulation similar to that already described. To fit the instrument for use, this column ought to be stationary, about the middle of the tube, at the common temperature of the atmosphere. The slightest variation of temperature occasions the movement of the coloured liquid; and a scale of equal parts measures the amount of the effect.

An insuperable objection to the air thermometer, is, that it is affected, not only by changes of temperature, but by variations of atmospheric pressure. Its utility consists in the great amount of the expansion of air, which, by a given elevation of temperature, is increased in bulk above twenty times more than mercury. Hence it is adapted to detect minute changes of temperature, which the mercurial thermometer would scarcely discover.

An important modification of the air thermometer has been invented by Mr. Leslie, and employed by him, with great advantage, in his interesting researches respecting heat. To this instrument he has given the name of, the Differential Thermometer. Its construction is as follows: "Two glass tubes of unequal length, each terminating in a hollow ball, and having their bores somewhat widened at the other ends (a small portion of sulphuric acid, tinged with carmine, being introduced into the ball of the longer tube), are joined together by the flame of a blowpipe, and afterwards bent nearly into the shape of the letter U, (see fig. 7.) the one flexure being made just below the joining, where the small cavity facilitates the adjustment of the instrument. This, by a little dexterity, is performed, by forcing, with the heat of the hand, a few minute globules of air from the one cavity into the other. The balls are blown as equal as the eye can judge, and from 4-10ths to 7-10ths of an inch diameter. The tubes are such as are drawn for thermometers, only with wider bores; that of the short one, to which the scale is affixed, must have an exact calibre of 1-50th, or 1-60th, of an inch. The bore of the long tube need not be so regular, but should be visibly larger, as the coloured liquid will then move quicker under any impression. Each leg of the instrument is from three to six inches in height, and the balls are from two to four inches apart. A moment's attention to the construction of this instrument will satisfy us, that it is affected only by the *difference* of heat in the corresponding balls; and is calculated to measure such difference with peculiar nicety. As long as both balls are of the same temperature, whatever this may be, the air contained in both will have the same elasticity, and, consequently, the intercluded coloured liquor, being pressed equally in opposite directions, must remain stationary. But if, for instance, the ball which holds a portion of the liquor be warmer than the other, the superior elasticity of the confined air will drive the liquid forwards, and make it rise, in the opposite branch, above the zero, to an elevation proportional to the excess of elasticity, or of heat." The amount of the effect is ascertained by a graduated scale, the interval between freezing and boiling being distinguished into 100 equal degrees. This instrument it must be obvious, cannot be applied to measure variations in the temperature of the surrounding atmosphere, for the reason already assigned. It is peculiarly adapted to ascertain the difference of the temperatures of two contiguous spots in the same atmosphere; for example, to determine the heat in the focus of a reflector.

Thermometers, filled with spirit of wine, are best adapted to the measurement of very low temperatures, at which mercury would freeze. The amount of the expansion of alcohol, also, which exceeds that of mercury above eight times, fits it for ascertaining very slight variations of temperature. But it cannot be applied to measure high degrees of heat; because the conversion of the spirit into vapour would burst the instrument.

The fluid, best adapted for filling thermometers, is mercury, which, though it expands less in amount than air, or alcohol, still undergoes this change to a sufficient degree; and, in consequence of its difficult conversion into vapour, may be applied to the admeasurement of more elevated temperatures. As a considerable saving of expense will accrue to the experimentalist, who is able to construct mercurial thermometers, I shall offer some rules for this purpose. In general, however, I should deem it preferable merely to superintend their construction, and to be satisfied, by actual inspection, that the necessary accuracy is observed; because much time must be unavoidably lost, in acquiring the manual skill which is essential to construct them neatly.

Thermometer tubes may be had at the glass-house, and of various philosophical-instrument makers. In purchasing them, those should be rejected that are not hermetically sealed at both ends; because the smallest condensation of moisture, which must take place when air is freely admitted within the tube, is injurious to the accuracy of the instrument. A small bottle of elastic gum [See Note 9.] should be provided, in the side of which a brass valve is fixed, or a piece of brass perforated by a small hole, to be occasionally stopped by the hand. A blow-pipe is also an essential part of the apparatus; and, in addition to one of the ordinary kind, it will be found useful to have one which is supplied with air by a pair of double bellows, worked by the foot.

Before proceeding to the construction of the thermometer, it is necessary to ascertain, that the tube is of equal diameter in different parts. This is done, by breaking off both of the sealed ends, immersing one of them an inch or two deep in clean and dry mercury, and then closing the other end with the finger. On withdrawing the tube from the mercury, a small column of that fluid remains in it, the length of which is to be examined, by laying the tube horizontally on a graduated ruler.* By inclin-

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* If the tube be of an extremely small bore, the mercury will not enter, and must be drawn in by the action of the elastic bottle, and not by the mouth.

ing the tube, this column may be gradually moved through its whole length; and if the tube be of uniform bore, it will measure the same in every part. Such a degree of perfection, however, is scarcely ever to be observed throughout tubes of considerable length; but, in general, a portion of the tube will be found perfect, of sufficient length for a thermometer, and this part is to be broken off.

On one end of the tube let the neck of the elastic bottle be firmly tied; and let the other end be heated by the flame of the blow-pipe, till the glass softens. The softened part must then be pressed, by a clean piece of metal, into the form of a rounded button; and to this the flame of the lamp must be steadily applied, till it acquires a white heat, and seems about to enter into fusion. To prevent its falling on one side, the tube, during this time, must be constantly turned round by the hand. When the heated part appears perfectly soft, remove it quickly from the lamp, and, holding the tube vertically, with the elastic bottle uppermost, press this last gently with the hand. The glass will be blown into a small ball, but not into one sufficiently thin for the purpose. To this the flame of the lamp must again be applied, turning it quickly round; and, on a second or third repetition of the process of blowing, the ball will be completely formed. The proportion of the size of the ball to the bore of the tube, can only be learned by some experience.

To fill the ball, which has been thus formed, with mercury, the air must first be expelled by holding it over the flame of an Argand's lamp, and then quickly immersing the open end of the tube in very clean and dry quicksilver. As the ball cools, the mercury will ascend, and will partly fill it. Let a paper funnel be tied firmly over the open end of the tube; into this pour a small portion of quicksilver, and apply the heat of the lamp to the ball. Any remaining portion of air will thus be expelled; and if the heat be raised, so as to boil the mercury, the ball and stem will be filled with mercurial vapour, the condensation of which, on removing the ball from the lamp, will occasion a pretty complete vacuum. Into this vacuum, quicksilver will descend from the paper cone; and the instrument will be completely filled. But for the purpose of a thermometer, it is necessary that the mercury should rise only to a certain height of the stem; and a few drops, may, therefore, be expelled by cautiously applying the heat of the lamp. To estimate whether the proper quantity of quicksilver has been left in the instrument, immerse the ball first in ice-cold water, and then in the mouth. The space between these two points will comprise 63 degrees, or pretty nearly 1-3d of the whole space between the freezing and boiling points of water. If the empty part of the tube exceeds, in length, about three times, the portion thus filled by the expanded quicksilver, we may proceed (when an instrument is wanted with a scale including only from 32° to 212°) to seal it hermetically; which is done as follows: The part to be sealed is first heated with the blow-pipe, and drawn out to a fine capillary tube; the bulb is then heated, till a few particles of quicksilver have fallen from the top of the tube: at this moment, the flame of another candle is directed, by the blow-pipe, on the capillary part of the tube, the candle is withdrawn from the ball, and the tube is sealed, at the instant when the mercury begins to descend. If this operation has been skilfully performed, so as to leave no air in the tube, the whole of the tube should be filled with quicksilver on holding the instrument with the ball uppermost.

To have very large degrees, the ball must bear a considerable proportion to the tube; but this extent of scale cannot be obtained without sacrificing, in some measure, the sensibility of the instrument. The whole of the process of constructing thermometers neatly and accurately, is connected with the possession of mutual skill, which practice only can confer; and it is scarcely possible, without the most tedious minuteness, to describe all the necessary precautions and manipulations. These will readily suggest themselves to a person who carries the above instructions into effect.

In graduating thermometers, the first step consists in taking the two fixed points. The freezing point is ascertained, by immersing, in thawing snow or ice, the ball and part of the stem; so that the mercury, when stationary, shall barely appear above the surface. At this place let a mark be made with a file. In taking the boiling point, considerable caution is required; and, for reasons which will afterwards be stated, attention must be paid to the state of the barometer, the height of which, at the time, should be precisely 29. 8. A tin vessel is to be provided, four or five inches longer than the thermometer, and furnished with a cover, in which are two holes. Through one of these, the thermometer stem must be passed (the bulb being within the vessel), so that the part at which the boiling point is expected, may be just in sight. The other hole may be left open; and the cover being fixed in its place, the vessel, containing a few inches of water at the bottom, is to be set on the fire. The thermometer will presently be wholly surrounded by steam; and when the mercury becomes stationary in the stem, its place must be marked. The scale of Fahrenheit is formed by transferring the intermediate space to paper by a pair of compasses, and dividing it into 180 degrees, the lowest being called 32, and the highest 212°. The scale of other countries, however, differs considerably; but these variations do not prevent the comparison of observations with different instruments, when the freezing and boiling points of water are agreed upon as fixed data. In the Appendix, rules will be given for converting the degrees of other scales to that of Fahrenheit.

III. *The dilatations and contractions of the fluid in the mercurial thermometer, are nearly proportional to the quantities of caloric, which are communicated to the same homogeneous bodies, or separated from them, so long as they retain the same form.*

Thus a quantity of caloric, required to raise a body 20 degrees in temperature, by the mercurial thermometer, is nearly double that which is required to raise it 10 degrees. Hence there appears to be a pretty accurate proportion between the increments or decrements of heat, and the increments and decrements of expansion in the mercury of a thermometer. On this principle, if equal quantities of hot and cold water be mixed together, and a thermometer be immersed in the hot water, and also in the cold, previously to the mixture, the instrument should point, after the mixture, to the arithmetical mean, or to half the difference of the separate heats, added to the less or substracted from the greater. This will be proved to be actually the fact, by the following experiment. Mix a pound of water at 172°, with a pound at 32°. Half the excess of the caloric of 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 must be observed.—See CRAWFORD on *Animal Heat*, p. 95, &c.

The experiments of De Luc, however, have shown, that the ratio of expansion does not, *strictly*, keep pace with the actual increments of temperature; and that the amount of the expansion increases with the temperature. Thus if a given quantity of mercury, in being heated from 32 to 122°, the first half of the scale, be expanded 14 parts, in being raised from 122 to 212, the higher half, it will be expanded 15 parts.

IV. *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, water at 32°, and various other bodies of different temperatures, they will soon affect the thermometer in the same degree. The same equalization of temperature is attained, though less quickly, when a heated body is placed in the vacuum of an air-pump. The rate of cooling in air is to that *in vacuo*, the temperatures being equal, nearly as five to two.

V. *Caloric escapes from bodies in two different modes.*—Part of it finds its way through space, independently of other matter, and with immeasurable velocity. In this state it has been called, radiant heat, or radiant caloric.

RADIANT CALORIC exhibits several interesting properties.

1. *Its reflection.* (*a.*) Those surfaces, that reflect light most perfectly, are not equally adapted to the reflection of caloric. Thus, a glass mirror, which reflects light with great effect when held before a blazing fire, scarcely returns any heat, and the mirror itself becomes warm. On the contrary, a polished plate of tin, or a silver spoon, when similarly placed, reflects, to the hand, a very sensible degree of warmth; and the metal itself remains cool. Metals, therefore, are much better reflectors than glass; and they possess this property, exactly according to their degree of polish.

(*b.*) Caloric is reflected according to the same law that regulates the reflection of light. This is proved by an interesting experiment of M. Pictet; the means of repeating which may be attained at a moderate expense. Provide two tin reflectors (*a* and *b*, fig. 45.), which may be 12 inches diameter, and segments of a sphere of nine inches radius. Each of these must be furnished, on its convex side, with the means of supporting it in a perpendicular position on a proper stand. Place the mirrors opposite to each other on a table, at the distance of from six to twelve feet. In the focus of one, let the ball of an air thermometer, *c*, be situated; and in that of the other, suspend a ball of iron, about four ounces in weight, and heated below ignition, or a small mattras of hot water, *d*, having previously interposed a screen before the thermometer. Immediately on withdrawing the screen, the depression of the column of liquid, in the air thermometer, evinces an increase of temperature in the instrument. In this experiment, the caloric flows first from the heated ball to the nearest reflector; from this it is transmitted, in parallel rays, to the surface of the second reflector, by which it is collected into a focus on the instrument. This is precisely the course that is followed by radiant light; for if the flame of a taper be substituted for the iron ball, the image of the candle will appear precisely on that spot (a sheet of paper being presented for its reception) where the rays of caloric were before concentrated.

(*c.*) When a glass vessel, filled with ice or snow, is substituted for the heated ball, the course of the coloured liquid in the thermometer will be precisely in the opposite direction; for its ascent will show, that the air in the ball is cooled by this arrangement. This experiment, which appears, at first view, to indicate the reflection of cold, presents, in fact, only the reflection of heat, but in an opposite direction; the ball of the thermometer being, in this instance, the hotter body.

(*d.*) In Mr. Leslie's "Inquiry into the Nature, &c. of Heat," a variety of important experiments are detailed, which show the influence of covering the reflectors with various substances, or of mechanically changing the nature of their surfaces, on their power of returning caloric.

2. Caloric is *refracted*, also, according to the same law that regulates the refraction of light. This interesting discovery we owe to Dr. Herschell, whose experiments and apparatus, however, cannot be understood without the assistance of a plate. For this reason, I refer to his paper in the 90th vol. of the Philosophical Transactions, or in the 7th vol. of the Philosophical Magazine.

3. The nature of the *surface* of bodies has an important influence over their power of *radiating* caloric.

To exhibit this influence experimentally, let a canister of planished block tin, forming a cube of six or eight inches, be provided, having an orifice at the middle of its upper side, from half an inch to an inch diameter, and the same in height. This orifice is intended to receive a cap having a small hole, through which a thermometer is inserted, so that its bulb may reach the centre of the canister. Let one side of the canister be covered with black paint; destroy the polish of another side, by scratching it with sand paper; tarnish a third with quicksilver; and leave the fourth bright. Then fill the vessel with boiling water.

The radiation of caloric from the blackened side is so much more abundant than from the others, as to be even sensible to the hand. Place it before a reflector, in lieu of the heated iron ball already described. The thermometer, in the focus of the second reflector, will indicate the highest temperature, or most copious radiation of caloric, when the blackened side is presented to the reflector; less when the tarnished or scratched side is turned towards it; and least of all from the polished side.

4. These varieties in the radiating power of different surfaces, are attended, as might be expected, with corresponding variations in the *rate of cooling*. If water in a tin vessel, all of whose sides are polished, cools through a given number of degrees in eighty-one minutes; it will descend through the same number in seventy-two minutes, if the surface be tarnished with quicksilver. Water, also, enclosed in a clean and polished tin ball, cools about twice more slowly than water in the same ball covered with oiled paper. Blackening the surface with paint, on the same principle, accelerates greatly the rate of cooling. These facts teach us, that vessels, in which fluids are to be long kept hot, should have their surfaces brightly polished; and they explain, among other things, the superiority of metallic tea-pots over those of earthen ware.

5. Radiant caloric is *absorbed* with different facility by different surfaces. This is only stating, in other terms, that surfaces are endowed with various powers of reflecting caloric. It may be proper, however, to offer some illustrations of the prinple under this form.

(*a.*) Expose the bulb of a sensible thermometer to the direct rays of the sun. On a hot summer's day it will probably rise, in this climate, to 108°. (Watson's Essays, v. 193.) Cover it with Indian ink, and again expose it in a similar manner. During the evaporation of the moisture it will fall; but as soon as the coating becomes dry, it will ascend to 118°, or upwards, of Fahrenheit, or 10° higher than when uncovered with the pigment. This cannot be explained, by supposing that the black coating is gifted with the power of retaining caloric, and preventing its escape; because, from experiments already related, it appears, that a similar coating accelerates the cooling of a body to which it is applied.

(*b.*) Colour has considerable influence over the absorption of caloric. This is shown by the following very simple experiment of Dr. Franklin.

On a winter's day, when the ground is covered with snow, take four pieces of woollen cloth, of equal dimensions, but of different colours, viz. black, blue, brown, and white, and lay them on the surface of the snow, in the immediate neighbourhood of each other. In a few hours, the black cloth will have sunk considerably below the surface; the blue almost as much; the brown evidently less; and the white will remain precisely in its former situation. Thus it appears, that the sun's rays are absorbed by the dark coloured cloth, and excite such a durable heat, as to melt the snow underneath; but they have not the power of penetrating the white. Hence the preference, generally given to dark coloured cloths during the winter season, and to light coloured ones in summer, appears to be founded on reason.

(*c.*) This experiment has been varied by Mr. Davy, in a manner which may be repeated at any season of the year. Take six similar pieces of sheet copper, each about an inch square, and colour the one white, another yellow, a third red, the fourth green, the fifth blue, and the sixth black. On the centre of one side of each piece, put a small portion of a mixture of oil and wax, or cerate, which melts at about 76°. Then expose their coloured surfaces, under precisely equal circumstances, to the direct rays of the sun. The cerate on the black plate will begin to melt perceptibly before the red; the blue next; then the green and the red; and, lastly, the yellow. The white will scarcely be affected, when the black is in complete fusion.

VI. Caloric passes, also, but much more slowly, through solid and liquid bodies, which are then termed, CONDUCTORS of caloric.

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

2. 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 vastly sooner from the end of the iron rod, than from the glass one; which shows, that iron conducts heat more quickly than glass.

Even the different metals possess very different powers of conducting caloric. An approximation to the degree in which they possess this property, may be attained by the following method, originally employed by Dr. Ingenhouz. Procure several solid cylinders, or rods, of the same size and shape, but of different metals. They may be six inches long, and 1-4th of an inch in diameter. Coat them, within about an inch of one end, with bees-wax, by dipping them into this substance when melted, and allowing the covering to congeal. Let an iron heater be provided, in which small holes have been drilled, that exactly receive the clean ends of the cylinders. After heating it below ignition, insert the cylinders in their places. The conducting power may be estimated by the length of wax coating melted from each in a given time. According to the experiments of Dr. Ingenhouz, the metals may be arranged in the following order: Silver possesses the highest conducting power; next gold; then copper and tin, which are nearly equal; and, below these, platina, iron, steel, and lead, which are greatly inferior to the rest.

3. Liquid and aeriform bodies convey heat on a different principle from that observed in solids, viz. by an actual change in the situation of their particles.

(*a.*) 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.

(*b.*) Into a cylindrical glass jar, four inches diameter, and twelve or fourteen deep, let a circular piece of ice be fitted three-and-a-half inches thick, and of rather less diameter than the jar. Or water may be poured into the jar to the depth of three-and-a-half inches, and allowed to congeal by exposure to a freezing atmosphere, or by surrounding it with a mixture of snow and salt. The ice is to be secured in its place by two slips of wood, crossing each other like two diameters of a circle, set at right angles to each other. Pour, over the cake of ice, water of 32° temperature, to the depth of two inches; and on its surface let there float a shallow circular wooden box, perforated with holes. From the cock of a tea-urn, filled with boiling water, and raised so that its spout may be about the top of the jar, suspend a number of moistened threads, the lower ends of which rest on the surface of the box. By this arrangement, when the cock is turned, the hot water will trickle down the threads, and will have its fall considerably broken. It will then spread over the surface of the box, and pass through the perforated holes to the cold water beneath, over which it will float without mixing with it.

Let the jar be thus completely filled with hot water. The ice will remain unmelted for several hours at the bottom of the vessel.

(*c.*) Fill a similar jar with hot water; and, having provided a cake of ice, of equal size with the former one, let it be placed on the surface of the water. In about thee minutes, the whole will be melted. Both these experiments are more striking, if the water, used for forming the cakes of ice, be previously coloured with litmus; for, in the latter experiment, the descending currents of cold water are thus made apparent.

(*d.*) These experiments may be varied, by freezing, in the bottom of a tube one inch wide, a portion of water, about two inches in depth. Then fill the tube with water of the common temperature, and hold it inclined over an Argand's lamp, so that the upper portion only of the tube may be heated. When thus disposed, the water may be made to boil violently at the surface, and yet the ice will not be melted. But if the experiments be reversed, and (the ice floating on the surface) heat be applied to the bottom of the tube, the ice will be liquefied in a few seconds.

(*e.*) Substituting water of the temperature of 41° for the boiling water used in experiment (*c*), Count Rumford found, that, in a given time, a much greater quantity of ice was melted by the cooler water. From these facts, he concluded, that water is a perfect non-conductor of caloric, and that it propagates caloric only in one direction, viz. upwards, in consequence of the motions which it occasions among the particles of the fluid. The Count inferred also, that if these motions could be suspended, caloric would cease to pass through water; and, with the view of deciding this question, he made the following experiments, which admit of being easily repeated. A cylindrical tin vessel must previously be provided, two inches in diameter, and two-and-a-half inches deep, having a moveable cover, perforated with a small aperture, for transmitting the stem of a thermometer, which is to be inserted so that its bulb may occupy the centre of the vessel.

(*f.*) Fill this vessel with water of the temperature of the atmosphere; let the cover be put in its place; and let the whole apparatus, except the scale of the thermometer, be immersed in water, which is to be kept boiling over a lamp. Observe how long a time is required to raise the water ftom its temperature at the outset to 180°, and remove it from its situation. Note, also, how long it takes to return to its former temperature.

(*g.*) Repeat the experiment, having previously dissolved in the water 200 grains of common starch. The thermometer will now require about half as long again to arrive at the same temperature. A similar retardation, and to a greater amount, is produced by the mixture of eider-down, cotton-wool, and various other substances, which are not chemically soluble in water, and which can diminish its conducting power in no other way than by obstructing the motion of its particles.

This inference, however, respecting the non-conducting power of water, has been completely set aside by the subsequent inquiries of Dr. Thomson and Mr. Murray, especially by a most decisive experiment of the latter. To establish the conducting power of water, it was justly deemed indispensable, that caloric should be proved to be propagated through that fluid downwards. This, on actual trial, it appeared to be; but it was objected, that the sides of the containing vessel might be the conductor. To obviate this objection, Mr. Murray contrived to congeal water into the form of a jar, capable of holding liquids. This was separately filled with linseed oil and with mercury. At a proper distance below the surface, the bulb of a thermometer was placed; and on the surface of the liquid rested a flat iron vessel, containing boiling water. Under these circumstances, the thermometer invariably rose; and though it ascended only a very few degrees, yet it must be recollected, that the cooling power of the sides of the vessel would effectually prevent any considerable elevation of temperature. This experiment, in conjunction with others, decisively proves, that water is a conductor, though a slow or imperfect one, of caloric.

VII. *Uncombined caloric promotes the action of chemical affinity.*—Thus, lead and tin do not combine till melted together. The filings of zinc and copper may be intimately blended together; and yet, with the aid of a magnifier, the two metals may be perceived to be perfectly distinct. When melted in a crucible, however, they combine, and form a homogeneous mass. 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.

SECTION II.

Caloric the Cause of Fluidity.

I. *The temperature of melting snow, or of thawing ice, is uniformly the same at all times, and in all places.*—This may be ascertained by the thermometer, which will always, when immersed in liquefying ice or snow, point to 32° of Fahrenheit, whatsoever may be the height of the barometer, or the elevation, above the sea, of the place where the experiment is made.

II. *The sensible heat, or temperature, of ice, is 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.

III. *Yet 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 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 imbibing caloric, because, according to Exp. IV. § 1. a colder body can never be in contact with a warmer one, without receiving caloric from it. 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.

IV. *The quantity of 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, but much below it, viz. 32°. All the excess of caloric in 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°.

V. *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*.

1. Dilute a portion of nitric acid with an equal weight of water; and, when the mixture has cooled, add to it a quantity of light fresh-fallen snow. On immersing the thermometer in the mixture, a very considerable reduction of temperature will be observed. This is owing to the absorption, and intimate fixation, of the uncombined caloric of the mixture, by the liquefying snow.

2. Mix quickly together equal weights of fresh-fallen snow at 32°, and of common salt cooled, by exposure to a freezing atmosphere, down to 32°. The two solid bodies, on admixture, will rapidly liquefy; and the thermometer will sink 32°, or to 0. To understand this experiment, it must be recollected, that the snow and salt, though at the freezing temperature of water, have each a considerable portion of uncombined caloric. Now, salt has a strong affinity for water; but the union cannot take place while the water continues solid. In order, therefore, to act on the salt, the snow absorbs all the uncombined caloric required for its liquefaction; and during this change, the free caloric, both of the snow and of the salt, amounting to 32°, becomes latent, and is concealed in the solution. This solution remains in a liquid state at 0 of Fahrenheit; but if a greater degree of cold be applied to it, the salt separates in a concrete form.

3. Most neutral salts, also, 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; of which the Table, given in the Appendix, exhibits an abstract.

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

4. Muriate of lime, when mixed with snow, produces a most intense degree of cold. 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, graduated to 50° below 0 of Fahrenheit, or still lower, should be employed. A few pounds of the salt are sufficient to congeal a large mass of mercury. By means of 13lbs. of the muriate, and an equal weight of snow, Messrs. Pepys and Allen froze 56lbs. 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 two or three 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.

In plate iv. fig. 42. a very simple and cheap apparatus is represented, which I have generally employed to freeze mercury. The dimensions will be given in the description of the plates. See Appendix.

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

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

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

1. 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°.

2. Expose to the atmosphere, when at a temperature below freezing (for example, at 25° of Fahrenheit), two equal quantities of water, in one only of which about a fourth of its weight of common salt has been dissolved. The saline solution will be gradually cooled, without freezing, to 25°. The pure water will gradually descend to 32°, and will there remain stationary a considerable time before it congeals. Yet while thus sta-

tionary, it cannot be doubted, that the pure water is yielding caloric to the atmosphere, equally with the saline solution ; for it is impossible that a warmer body can be surrounded by a cooler one, without imparting caloric to the latter. The reason of this equable temperature is well explained by Dr. Crawford. (*On Heat*, p. 80.) Water, he observes, during freezing, is acted upon by two opposite powers : it is deprived of caloric by exposure to a medium, whose temperature is below 32° ; and it is supplied with caloric, by the evolution of that principle from itself, viz. of that portion which constituted its fluidity. As these powers are exactly equal, the temperature of the water must remain unchanged, till the caloric of fluidity is all evolved.

3. The evolution of caloric, during the congelation of water, is well illustrated by the following experiment of Dr. Crawford :—Into a round tin vessel put a pound of powdered ice ; surround this by a mixture of snow and salt in a larger vessel ; and stir the ice in the inner one, till its temperature is reduced to 4° of Fahrenheit. To the ice thus cooled, add a pound of water at 32°. One-fifth of this will be frozen ; and the temperature of the ice will rise from 4° to 32°. In this instance, the caloric, evolved by the congelation of one-fifth of a pound of water, raises the temperature of a pound of ice 28 degrees.

4. 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.

SECTION III.

Caloric the Cause of Vapour.

1. *Every liquid, when of the same degree of chemical purity, and under equal circumstances of atmospheric pressure, has one peculiar point of temperature, at which it invariably boils.*—Thus, pure water always boils at 212°, alcohol at 176°, and ether at 98° Fahrenheit. The boiling point of water may be readily ascertained, by immersing a thermometer in water boiling over the fire. As there is some danger in applying heat directly to a vessel containing either ether or alcohol, the ebullition of these fluids may be shown, by immersing the vessel containing them in water, the temperature of which may be gradually raised. The appearance of boiling is owing to the formation of vapour at the bottom of the vessel, and its escape through the heated fluid above it.

II. *Steam has exactly the same temperature as boiling water.*—Let a tin vessel be provided, having two holes in its cover, one of which is just large enough to admit the stem of 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, leaving the other aperture open for the escape of vapour. 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.

III. *The boiling point of the same fluid varies, under different degrees of atmospheric pressure.*—Thus, water, which has been removed from the fire, and ceased to boil, has its ebullition renewed, when it is placed under a receiver, the air of which is quickly exhausted by an air-pump. Alcohol and ether, confined under an exhausted receiver, boil violently at the temperature of the atmosphere. In general, liquids boil *in vacuo*, with about 140° less of heat, than are required under a mean pressure of the atmosphere. (Black's Lectures, i. 151.) [See Note 10.]

The influence of a diminished pressure in facilitating ebullition, may be inferred also from the following very simple experiment : Place, over a lamp, a Florence flask, about three-fourths filled with water ; let it boil briskly during a few minutes ; and, immediately on removing it from the lamp, cork it tightly : 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. Applying the heat of the lamp to the bottom of the flask, the water will again cease to boil. 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 steam ; [see Note 11.] and the suspension of the boiling, on re-applying the heat, to the renewed pressure on the surface of the hot water, occasioned by the formation of fresh steam.

From these facts, it may be inferred, that the particles of caloric are mutually repulsive, and that 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 aeriform bodies, and is chiefly counteracted by the pressure of the atmosphere.

Were this counteracting cause removed, many bodies, which at present have a liquid form, would cease to be such, and would be changed into a gaseous state. Precisely the same effect, therefore, results from the prevalence of either of these forces. Add to certain liquids a quantity of caloric, in other words, place them in a high temperature, and they are immediately converted into gases : or, their temperature remaining the same, diminish the weight of the atmosphere ; and the caloric, which they naturally contain, exerts its repulsive tendency with equal effect, and they are in like manner converted into gases. These facts are best shown by the following experiments on ether :

1. 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.

2. Ether is changed into gas [see Note 12.] by diminishing the weight of the atmosphere. Into a glass tube, about six inches long, and half an inch in 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 re-admitting the air into the receiver, the gas is again condensed into a liquid form.

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

This experiment requires, for its performance, a strong iron vessel, called a Papin's digestor, a plate of which may be seen in Gren's Chemistry. That the boiling point of water, and the temperature of steam, are raised by an increased atmospheric pressure, may be shown, however, by means of the small boiler represented plate v. fig. 46., which will be found extremely useful in experiments on this subject. Its precise size, and directions for its construction, will be given in the Appendix.

On the cock *c* may be screwed, occasionally, a valve, loaded in the proportion of fourteen pounds to the square inch. The boiler being rather more than half filled with water, and the perforated cap *d* being screwed into its place, the ball of the thermometer will be an inch or more above the surface of the water, and will indicate its temperature, as well as that of the steam, both being in all cases precisely the same. Allowing the steam to escape through the cock *c*, before affixing the valve, the temperature of the steam, under a mean atmospheric pressure, will be 212°. When an additional atmosphere is added by the weighted valve, it will rise to above 240; by a valve twice as heavy as the first, or loaded in the proportion of twenty-eight pounds to the square inch, the temperature of the steam will be raised to nearly 270. This is as far as it is safe to carry the experiment; but by substituting a strong iron vessel, the numbers have been obtained, which will be found in the form of a Table, in the Appendix.

V. *The absorption of caloric, during evaporation, shewn by experiment.*

Moisten a thermometer with alcohol, 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 Philosophical Transactions, 1781, p. 509), water may be frozen in a thin and small glass ball, by means of ether. The same effect may be obtained, also, by immersing a tube, containing water at the bottom, in a glass of ether, which is to be 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.

VI. *The fixation of caloric in water, by its conversion into steam, may be shown by the following experiments:*—1. Let a pound of water at 212°, and eight pounds of iron filings at 300°, be suddenly mixed together. A large quantity of vapour will be instantly generated; and the temperature of the mixture will be only 212°: but that of the vapour produced, is also not more than 212°; and the steam must therefore contain, in a latent or combined form, all the caloric which raised the temperature of eight pounds of iron filings from 212° to 300°.

2. The quantity of caloric, which thus becomes latent during the formation of steam, may be approximated, by repeating the following experiment of Dr. Black: He placed two cylindrical flat-bottomed vessels of tin, five inches in diameter, and containing a small quantity of water at 50°, on a red-hot iron plate, of the kind used in kitchens. In four minutes the water began to boil, and in twenty minutes the whole was boiled away. In four

minutes, therefore, the water received 162° of temperature, or 40½° in each minute. If we suppose, therefore, that the heat continues to enter the water at the same rate, during the whole ebullition, we must conclude that $40\frac{1}{2}^\circ \times 20^\circ = 810^\circ$ have entered the water, and are contained in the vapour.

VII. *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 1 gallon of water at 212°. The temperature of the water will be raised about 1½°. Condense by a common still-tub, 1 gallon of water, from the state of steam, by 100 gallons of water, at the temperature of 50°. The water will be raised 11°. Hence, 1 gallon of water, condensed from steam, raises the temperature of 100 gallons of cold water 9½° more than 1 gallon of boiling water; and, by an easy calculation, it appears, that the caloric imparted to the 100 gallons of cold water by 8 pounds of steam, if it could be condensed in 1 gallon of water, would raise it to 950°. (Black's Lectures, i. 169.)

For exhibiting the same fact, by means of a small apparatus, which may be placed on a table, and with the assistance only of a lamp, the boiler already described (fig. 46.) will be found extremely well adapted. The right-angled pipe *e* must be screwed, however, into its place, and must be made to terminate at the bottom of a jar, containing a known quantity of water of a given temperature. The conducting-pipe and the jar should be wrapped round with a few folds of flannel. The apparatus being thus disposed, let the water in the boiler be heated by an Argand's lamp, with double concentric wicks, till steam issues in considerable quantity through the cock *c*, which is then to be closed. The steam will now pass through the right-angled pipe into the water contained in the jar, which will condense the steam, and will have its temperature very considerably raised. Ascertain the augmentation of temperature and weight; and the result will show, how much a given weight of water has had its temperature raised by a certain weight of condensed steam. To another quantity of water, equal, in weight and temperature to that contained in the jar at the outset of the experiment, add a quantity of water at 212°, equal in weight to the condensed steam; it will be found, on comparison of the two resulting temperatures, that a given weight of steam has produced, by its condensation, a much greater elevation of temperature, than the same quantity of boiling water. This will be better understood by the following example, taken from actual experiment:

Into eight ounces of water, at 50° Fahrenheit, contained in the glass jar, *f*, fig. 46, steam was passed from the boiler, till the temperature of the water in the jar rose to 173°. On weighing the water, it was found to have gained 8½ drachms; that is, precisely 8½ drachms of steam had been condensed, and had imparted its heat to the water.—To facilitate the explanation of this experiment, it is necessary to premise the following remarks.

To measure the whole quantities of caloric contained in different bodies, is a problem in chemistry which has not yet been solved. But the quantities of caloric, added to, or subtracted from, different bodies (setting out from a given temperature) may, in many cases, be measured and compared with considerable accuracy. Thus, if, as has been already stated, two pounds of water at 120° be mixed with two pounds at 60°, half the excess of caloric in the hot water will pass to the colder portion; that is, the hot water will be cooled 30°, and the cold will receive 30° of temperature; and if the experiment be conducted with proper precautions, 90°, the arithmetical mean of the temperature of the separate parts, will be the temperature of the mixture. If 3 pounds of water at 100° be mixed with 1 pound at 60, we shall have the same quantity of heat as before, viz. 4 pounds at 90°. Hence, if the quantity of water be multiplied by the temperature, the product will be a comparative measure of the quantity of caloric which the water contains, exceeding the zero of the thermometer employed.

Thus, in the last Example,

3 × 100 = 300 = the caloric above zero in the first portion.
1 × 60 = 60 = the caloric above zero in the second do.

The sum, 360, = the caloric above zero in the mixture.

Dividing 360 by 4, the whole quantity of water, we obtain 90°, the temperature of the mixture.

This method of computation may be conveniently applied to a variety of cases. Thus, in the foregoing experiment, 8½ drachms of steam at 212°, added to 64 drachms of water at 50°, produced 72½ drachms of water at 173°. Now,

72½ × 173 = 12542½ = whole heat of the mixture.
64 × 50 = 3200 = heat of 64 drachms, one of the component parts.
9342½ = heat of 8½ drachms, the other component part.

Therefore $9342\frac{1}{2}$ divided by $8\frac{1}{2}=1099$, should have been the temperature of the latter portion (viz. $8\frac{1}{2}$ drachms), had none of its heat been latent : and $1099-212=887$ gives the latent heat of the steam. This result does not differ more than might be expected, owing to the unavoidable inaccuracies of the experiment, from Mr. Watt's determination, which states the latent heat of steam at 900, or from that to 950°. (Black's Lect. i. 174.)

The large quantity of caloric, latent in steam, renders its application extremely useful for practical purposes. Thus, water may be heated, as in the foregoing experiment, at a considerable distance from the source of heat, by lengthening the conducting-pipe *e*. This furnishes us with a commodious method of warming the water of baths, which, in certain cases of disease, it is of importance to have near the patient's bed-room ; for the boiler, in which the water is heated, may thus be placed on the ground-floor, or in the cellar of a house ; and the steam conveyed by pipes into an upper apartment. Steam may also be applied to the purpose of heating or evaporating water, by a modification of the apparatus. Fig. 46. *g*, represents the apparatus for boiling water by the condensation of steam, without adding to its quantity ; a circumstance occasionally of considerable importance. The steam is received between the vessel, which contains the water to be heated, and an exterior case ; it imparts its caloric to the water, through the substance of the vessel ; is thus condensed, and returns to the boiler by the perpendicular pipe. An alteration of the form of the vessel adapts it to evaportion (fig. 46. *h*). This method of evaporation is admirably suited to the concentration of liquids, that are decomposed, or injured, by a higher temperature than that of boiling water, such as medicinal extracts ; to the drying of precipitates, &c. In the employment of either of these vessels, it is expedient to surround it with some slow conductor of heat. On a small scale, a few folds of woolen cloth are sufficient ; and, when the vessel is constructed of a large size for practical use, this purpose is served by the brick-work in which it is placed.

SECTION IV.

Specific Caloric.

Equal weights of the *same* body, at the same temperature, contain similar quantities of caloric. But equal weights of *different* bodies, at the same temperature, contain unequal quantities of caloric. The quantity of caloric, which one body contains, compared with that contained in another,is called its *specific caloric* ; and the power or property, which enables bodies to retain different quantities of caloric, has been called *capacity for caloric*. The method of determining the specific caloric, or comparative quantities of caloric in different bodies, is as follows :

It has already been observed, that equal weights of the *same* body, at different temperatures, give, on admixture, the arithmetical mean. Thus, the temperature of a pint of hot water and a pint of cold, is, after mixture, very nearly half way between that of the two extremes. But this is not the case, when equal quantities of *different* bodies, at different temperatures, are employed.

(*a*.) If a pint of quicksilver at 100° Fahrenheit, be mixed with a pint of water, at 40°, the resulting temperature will not be 70° (the arithmetical mean), but only 60°. Hence the quicksilver loses 40° of heat, which nevertheless raise the temperature of the water only 20° ; in other words, a larger quantity of caloric is required to raise the temperature of a pint of water, than that of a pint of mercury, through the same number of degrees. Hence it is inferred, that water has a greater capacity for caloric than is inherent in quicksilver.

(*b*.) The experiment may be reversed, by heating the water to a greater degree than the quicksilver. If the water be at 100°, and the mercury at 40°, the resulting temperature will be nearly 80 ; because the pint of hot water contains more caloric, than is necessary to raise the quicksilver to the arithmetical mean.

(*c*.) Lastly, if we take 2 measures of quicksilver to 1 of water, it is of no consequence which is the hotter ; for the resulting temperature is always the mean between the two extremes ; for example, 70°, if the extremes be 100° and 40°. Here, it is manifest, that the same quantity of caloric, which makes one measure of water warmer by 30°, is sufficient for making two measures of quicksilver warmer by the same number. Quicksilver has, therefore, a less capacity than water for caloric, in the proportion, when equal measures are taken, of one to two.

If, instead of equal *bulks* of quicksilver and water, we had taken equal *weights*, the disparity between the specific caloric of the mercury and water would have been still greater. Thus a pound of water at 100°, mixed with a pound of mercury at 40°, gives a temperature of 97½, or 27½ above the arithmetical mean. In this experiment, the water, being cooled from 100° to 97½, has lost a quantity of caloric reducing its temperature only $2\frac{1}{2}$ degrees; but this caloric, communicated to the pound of mercury, has produced, in its temperature, a rise of no less than $57\frac{1}{2}$ degrees. Therefore, a quantity of caloric, necessary to raise the temperature of a pound of water $2\frac{1}{2}°$, is sufficient to raise that of a pound of mercury to $57\frac{1}{2}°$; or, by the rule of proportion, the caloric, which raises the temperature of a pound of water 1°, will raise that of a pound of quicksilver about 23°. Hence it is inferred, that the quantity of caloric contained in water, is to that contained in the same *weight* of quicksilver as 23 to 1. Or, stating the caloric of water at 1, that of quicksilver will be $\frac{1}{23}$ part of 1, or about 0,0435*.

When this comparison is extended to a great variety of bodies, they will be found to differ very considerably in their capacities for caloric. The results of numerous experiments of this kind are comprised in a Table of specific caloric: (see the Appendix.)

The capacities of bodies for caloric influence, considerably, the rate at which they are heated and cooled. In general, those bodies are most slowly heated, and cool most slowly, which have the greatest capacities for heat. Thus, if water and quicksilver be set, in similar quantities, and at equal distances, before the fire, the quicksilver will be much more rapidly heated than the water; and, on removal from the fire, it will cool with proportionally greater quickness than the water. By ascertaining the comparative rates of cooling, we may even determine, with tolerable exactness, the specific caloric of bodies; and particularly of one class (the gases), which are not easily compared in any other way: (See Leslie on Heat, chap. xxi.)

CHAPTER IV.

OF LIGHT.

THE laws of light, so far as they relate to the phenomena of its movement, and to the sense of vision, constitute the science of OPTICS; and are the objects, therefore, not of Chemistry, but of Natural Philosophy. Light, however, is capable of producing important chemical effects, and of entering into various chemical combinations. Its action is, for the most part, exerted in de-

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* The above numbers, which differ from those commonly stated, are given on the authority of Mr. Dalton.

oxidizing bodies; and facts of this kind cannot be perfectly understood, until two important classes of bodies have been described, viz. those of oxides and of acids. In this place, therefore I shall state only a few of its least complicated effects; and shall trace its agency on different bodies, as they become the objects of experiment in the sequel.

I. Light, in the state in which it reaches the organ of vision, it is well known, is not a simple body, but is capable of being divided, by the prism, into seven primary rays or colours, viz. red, orange, yellow, green, blue, indigo, and violet. These are refrangible in the above order, the red being least refrangible, and the violet most so. The image formed by the different rays, thus separated, constitutes the SOLAR SPECTRUM.

II. Heat and light are not present, in corresponding degrees, in different parts of the solar spectrum. With respect to the *illuminating* power of each colour, Dr. Herschell found that the red rays are far from having it in an eminent degree. The orange possess more of it than the red; and the yellow rays illuminate objects still more perfectly. The maximum of illumination lies in the brightest yellow or palest green. The green itself is nearly equally bright with the yellow; but from the full deep green, the illuminating power decreases very sensibly. That of the blue is nearly on a par with that of the red; the indigo has much less than the blue, and the violet is very deficient. (Phil. Trans. 1800, p. 267.)

III. The *heating* power of the rays follows a different order.—If the bulb of a very sensible air-thermometer be moved, in succession, through the differently coloured rays, it will be found to indicate the greatest heat in the red rays; next in the green; and so on, in a diminishing progression, to the violet. The precise effects of the different rays, determined by Dr. Herschell's experiments, are as follows:

	The thermometer rose		
In the blue,	in 3 minutes	from 55°	to 56°
— — green	in 3 d°	—— 54	to 58
— — yellow	in 3 d°	—— 56	to 62
— — full red	in 2½ d°	—— 56	to 72
— confines of red	in 2½ d°	—— 58	to 73½

IV. When the thermometer is removed entirely out of the confines of the red rays, but with its ball still in the line of the spectrum, it rises even higher than in the red rays; and continues to rise, till removed half an inch beyond the extremity of the red ray. In this situation, quite out of the visible light, the thermometer rose in 2½ minutes from 61 to 79. The ball of the thermometer, employed for this purpose, should be extremely small*, and should be blackened with Indian ink. An air thermometer is better adapted than a mercurial one, to exhibit the minute change of temperature that ensues. These invisible heat-making rays may be reflected by the mirror, and refracted by the lens, exactly in the same manner as the rays of light.

V. Beyond the confines of the spectrum on the other side, viz. a little beyond the violet ray, the thermometer is not affected; but in this place it is remarkable, that there are also invisible rays of a different kind, which exert all the chemical effects of the rays of light, and with even greater energy. One of the chemical properties of light, it will hereafter be stated, is, that it speedily changes, from white to black, the fresh-precipitated muriate of silver. (See chap. xviii. sect. 4.) This effect is produced most rapidly by the direct light of the sun; and the rays, as separated by the prism, have this property in various degrees. The blue rays, for example, effect a change of the muriate of silver in fifteen seconds, which the red require twenty minutes to accomplish; and, generally speaking, the power diminishes as we recede from the violet extremity. But entirely out of the spectrum, and beyond the violet rays, the effect is still produced. Hence it appears, that the solar beams consist of three distinct kinds of rays: of those that excite heat, and promote oxidation; of illuminating rays; and of de-oxidizing rays. A striking illustration of the different power of these various rays is furnished, by their effect on phosphorus. In the rays beyond the red extremity, phosphorus is heated, smokes, and emits white fumes; but these are presently suppressed, on exposing it to the de-oxidizing rays, which lie beyond the violet extremity.

VI. There is an exception, however, as stated by Dr. Wollaston, to the de-oxidizing power of the rays above-mentioned. The substance, termed gum-guaiacum, has the property, when exposed to the light, of changing from a yellowish colour to green; and this effect he has ascertained to be connected with the absorption of oxygen. Now in the most refrangible rays, which would fall beyond the violet extremity, he found that this

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* Excellent thermometers for this purpose, and others requiring great sensibility, are made by Mr. Crichton, of Glasgow, and Mr. Cary, of London.

substance became green, and was again changed to yellow by the least refrangible. This is precisely the reverse of what happens to muriate of silver, which is blackened, or de-oxidized, by the most refrangible; and has its colour restored, or is again oxygenized, in the least refrangible rays.

VII. Certain bodies have the property of absorbing the rays of light in their totality; of retaining them for some time; and of again evolving them unchanged, and unaccompanied by sensible heat. Thus, in an experiment of Du Fay, a diamond exposed to the sun, and immediately covered with black wax, shone, in the dark, on removing the wax, at the expiration of several months. Bodies, gifted with this property, are called SOLAR PHOSPHORI. Such are Canton's, Baldwin's, Homberg's and the Bolognian phosphori, which will be described hereafter. To the same class belong several natural bodies, which retain light, and give it out unchanged. Thus snow is a natural solar phosphorus. So also is, occasionlly, the sea when agitated; putrid fish have a similar property; and the glow-worm belongs to the same class. These phenomena are independent of every thing like combustion; for artificial phosphori, after exposure to the sun's rays, shine in the dark, when placed in the vacuum of an air-pump, or under water, &c. where no air is present to effect combustion.

VIII. From solar phosphori, the extrication of light is facilitated by the application of an elevated temperature; and, after having ceased to shine at the ordinary temperature, they again emit light when exposed to an increase of heat. Several bodies, which do not otherwise give out light, evolve it, or become phosphorescent, when heated. Thus, powdered fluate of lime becomes luminous, when thrown on an iron plate raised to a temperature rather above that of boiling water. The yolk of an egg, when dried, becomes luminous on being heated; and so also does tallow during liquefaction. To exhibit the last mentioned fact, it is merely necessary to place a lump of tallow on a coal, heated below ignition, making the experiment in a dark room.

IX. Attrition, also, evolves light. Thus, two pieces of common bonnet cane, rubbed strongly against each other in the dark, emit a faint light. Two pieces of borax have the same property much more remarkably.

X. Light is disengaged in various cases of chemical combination. Whenever combustion is a part of the phenomena, this is well known to happen; but light is evolved, also, in other instances, where nothing like combustion goes forwards. Thus, fresh-prepared pure magnesia, added suddenly to highly concentrated sulphuric acid, exhibits a red heat.

XI. For measuring the relative intensities of light from various sources, an instrument has been contrived, called the PHOTOMETER. That of Count Rumford, described in the 84th vol. of the Philosophical Transactions, being founded on optical principles, does not fall strictly within the province of this work. It is constructed on the principle, that the power of a burning body, to illuminate any defined space, is directly as the intensity of the light, and inversely as the square of the distance. If two unequal lights shine on the same surface at equal obliquities, and an opaque body be interposed between each of them and the illuminated surface, the two shadows must differ in intensity or blackness; for the shadow formed by intercepting the greater light will be illuminated by the lesser light only; and, reversely, the other shadow will be illuminated by the greater light; that is, the stronger light will be attended with the deeper shadow. But it is easy, by removing the stronger light to a greater distance, to render the shadow, which it produces, not deeper than that of the smaller, or of precisely the same intensity. This equalization being effected, the quantity of light emitted by each lamp, or candle, will be as the square of the distance of the burning body from the white surface.

The photometer of Mr. Leslie is founded on a different principle, viz. that light, in proportion to its absorption, produces heat. The degree of heat produced, and consequently of light absorbed, is measured by the expansion of a confined portion of air. A minute description of the ingenious instruments contrived by Mr. Leslie with this view, may be seen in his work on Heat, or in the 3d vol. of Nicholson's 4to. Journal. In its construction, it bears a considerable resemblance to the differential thermometer, already described, page 22, and represented plate i. fig. 7. As both the balls of the latter instrument, however, are transparent, no change ensues in the situation of the coloured liquid when it is exposed to the variations of light. But, in the photometer, one of the balls is rendered opaque, either by tinging the glass, or by covering it with a pigment; and hence this ball, absorbing the incident light which passes freely through the transparent one, the air included in it becomes warmer than that of the other ball, and, by its greater elasticity, forces the liquid up the opposite leg of the instrument. A graduated scale measures the amount of the effect; and a glass covering defends the photometer from being influenced by the temperature of the atmosphere.

CHAPTER V.

OF GASES.

SECTION I.

Of the Apparatus for Gases.

For performing the necessary experiments on gases, many articles of apparatus are essential, that have not hitherto been described. It may assist the student in obtaining the necessary instruments, if a few of the most essential be here enumerated. In this place, however, I shall mention such only, as are necessary in making a few general experiments on this interesting class of bodies.

The apparatus, required for experiments on gases, consists partly of vessels fitted for containing the materials that afford them, and partly of vessels adapted for the reception of gases, and for submitting them to experiment.

1. For procuring such gases as are producible without a very strong heat, glass bottles, furnished with ground stoppers and bent tubes, are sufficient, (plate ii. fig. 18.). 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 by a tin pipe, will serve for obtaining some of the gases.

Those gases 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 gases where it may be requisite.

A very convenient apparatus, for obtaining such gases as cannot be disengaged without a red heat, is sold at the shops for philosophical apparatus in London. It consists of a cast-iron retort, to which a jointed metallic conducting tube is fitted by grinding; and by means of which the gas may be conveyed in any direction, and to any moderate distance. (See Murray's Chemistry, vol. i. pl. vi. fig. 50.)

2. For receiving the gases, glass jars, of various sizes (figs. 21, 22, 23.), are required, some of which should be furnished with necks at the top, fitted with ground stoppers. Others should be provided with brass caps, and screws, for the reception of air-cocks (fig. 22.). Of these last (the air-cocks), several will be found necessary; and, to some of them, bladders, or elastic bottles, should be firmly tied, for the purpose of transferring gases. These jars will also be found extremely useful in experiments on the properties and effects of the gases. 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. Plate iv. fig. 41. *ff* exhibits a section of this apparatus, which has been termed the pneumato-chemical trough, or pneumatic cistern. Its size may vary with that of the jars employed; and, about two or three inches 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. In this shelf should be a few small holes, to which inverted funnels may be soldered.

A glass tube, about eighteen inches long, and three quarters of an inch diameter (fig. 24.), 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 experimentalist should be furnished with air funnels (fig. 19.), for transferring gases from wide to narrow vessels.

An apparatus, almost indispensable in experiments on this class of bodies, is a GAZOMETER, [See Note 13.] which enables the chemist to collect and to preserve large quantities of gas, with the aid of only a few pounds of water. In the form of this apparatus there is considerable variety; but, at present, I have no other view than that of explaining its general construction and use. It consists of an outer fixed vessel *d* (plate iv. fig. 35.), and an inner moveable one *c*, both of japanned iron. The latter slides easily up and down within the other, and is suspended by cords passing over pulleys, to which are attached the counterpoises, *ee*. To avoid the encumbrance of a great weight of water, the outer vessel *d* is made double, or is composed of two cylinders, the inner one of which is closed at the top and at the bottom. The space only of about half an inch is left between the two cylinders, as shown by the dotted lines. In this space the vessel *c* may move freely up and down. The interval is filled with water as high as the top of the inner cylinder. The cup, or rim, at the top of the outer vessel, is to prevent the water from overflowing, when the vessel *c* is forcibly pressed down, in which situation it is placed whenever gas is about to be collected. The gas enters from the vessel in which it is produced, by the communicating pipe *b*, and passes along the perpendicular pipe marked by dotted lines in the centre, into the cavity of the vessel *c*, which continues rising till it is full.

To transfer the gas, or to apply it to any purpose, the cock *b* is to be shut, and an empty bladder, or bottle of elastic gum, furnished with a stop-cock, to be screwed on *a*. When the vessel *c* is pressed down with the hand, the gas passes down the central pipe, which it had before ascended, and its escape at *b* being prevented, it finds its way up a pipe which is fixed to the outer surface of the vessel, and which is terminated by the cock *a*. By means of an ivory mouth-piece screwed upon this cock, the gas, included in the instrument, may be respired; the nostrils being closed by the fingers. When it is required to transfer the gas, into glass jars standing inverted in water, a crooked tube may be employed, one end of which is screwed upon the cock *b*; while the other aperture is brought under the inverted funnel, fixed into the shelf of the pneumatic trough.—See fig. 41. *c*.

Several alterations have been made in the form of this apparatus; but they are principally such as add merely to its neatness and beauty, and not to its utility; and they render it less easy of explanation. The counterpoises *ee* are now, generally, concealed in the framing, and the vessel *c* is frequently made of glass.

When large quantities of gas are required (as at a public lecture), the gas-holder, plate iv. fig. 36. will be found extremely useful. It is made of tinned iron plate, japanned both within and without. Two short pipes, *a* and *c*, terminated by cocks, proceed from its sides, and another, *b*, passes through the middle of the top or cover, to which it is soldered, and reaches within half an inch of the bottom. It will be found convenient also to have an air-cock, with a very wide bore, fixed to the funnel at *b*. When gas is to be transferred into this vessel from the gazometer, the vessel is first completely filled with water through the funnel, the cock *a* being left open, and *c* shut. By means of a horizontal pipe, the aperture *a* is connected with *a* of the gazometer. The cock *b* being shut, *a* and *c* are opened, and the vessel *c* of the gazometer, fig. 35. gently pressed downwards with the hand. The gas then descends from the gazometer till the air-holder is full, which may be known by the water ceasing to escape through the cock *c*. All the cocks are then to be shut, and the vessels disunited. To apply this gas to any purpose, an empty bladder may be screwed on *a*; and water being poured through the funnel *b*, a corresponding quantity of gas is forced into the bladder. By lengthening the pipe *b*, the pressure of a column of water may be added; and the gas being forced through *a* with considerable velocity, may be applied to the purpose of a blow-pipe, &c. &c.*

The gazometer, already described, is fitted only for the reception of gases that are confinable by water; because quicksilver would act on the tinning and solder of the vessel, and would not only be spoiled itself, but would destroy the apparatus. Yet an instrument of this kind, in which mercury can be employed, is peculiarly desirable, on account of the great weight of that fluid; and two varieties of the mercurial gazometer have therefore been invented. The one, of glass, is the contrivance of Mr. Clayfield, and may be seen represented in the plate prefixed to Mr. Davy's Researches. In the other, invented by Mr. Pepys, the cistern for the mercury is of cast-iron. A drawing and representation of it may be found in the 5th vol. of the Philosophical Magazine; but as neither of these instruments are essential to the chemical student, and as they are required only in experiments of research, I deem it sufficient to refer to the minute descriptions of their respective inventors.

For those gases that are absorbed by water, a mercurial trough is necessary. For the mere exhibition of a few experiments on these condensible gases, 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. See plate iii. fig. 31. *ff.*

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* Descriptions and figures of improved gas-holders may be seen in the 13th vol. of the Philosophical Magazine.

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

1. When a glass jar, closed at one end, is filled with water, and held with its mouth downwards, in however small a quantity of water, the fluid is retained in its place by the pressure of the atmosphere on the surface of the exterior water. Fill in this manner, and invert, on the shelf of the pneumatic trough, one of the jars, which is furnished with a stopper (fig. 23). The water will remain in the jar so long as the stopper is closed; but immediately on removing it, the water will descend to the same level within as without; for it is now pressed, equally upwards and downwards, by the atmosphere, and falls therefore in consequence of its own gravity.

2. Place the jar, filled with water and inverted, over one of the funnels of the shelf of the pneumatic trough. Then take another jar, filled (as it will be of course) with atmospherical air. Place the latter with its mouth on the surface of the water; and on pressing it in the same position below the surface, the included air will remain in its situation. Bring the mouth of the jar beneath the funnel in the shelf, and incline it gradually. The air will now rise in bubbles, through the funnel, into the upper jar, and will expel the water from it into the trough.

3. Let one of the jars, provided with a stop-cock at the top, be placed full of air on the shelf of the trough. Screw upon it an empty bladder; open the communication between the jar and the bladder, and press the former into the water. The air will then pass into the bladder, till it is filled; and when the bladder is removed from the jar, and a pipe screwed upon it, the air may be again transferred into a jar inverted in water.

4. For the purpose of transferring gases from a wide vessel standing over water, into a small tube filled with and inverted in mercury, I have long used the following contrivance of Mr. Cavendish. A tube, eight or ten inches long, and of very small diameter, is drawn out to a fine bore, and bent at one end, so as to resemble the Italic letter *l*. The point is then immersed in quicksilver, which is drawn into the tube till it is filled, by the action of the mouth. Placing the finger over the aperture at the straight end, the tube is next conveyed through the water, with the bent end uppermost, into an inverted jar of gas. When the finger is removed, the quicksilver falls from the tube into the

trough, or into a cup placed to receive it, and the tube is filled with the gas. The whole of the quicksilver, however, must not be allowed to escape ; but a column must be left, three or four inches long, and must be kept in its place by the finger. Remove the tube from the water ; let an assistant dry it with blotting paper ; and introduce the point of the bent end into the aperture of the tube standing over quicksilver. On withdrawing the finger from that aperture which is now uppermost, the pressure of the column of quicksilver, added to the weight of the atmosphere, will force the gas from the bent tube into the one standing in the mercurial trough.

On every occasion, when it is necessary to observe the precise quantity of gas, at the commencement and close of an experiment, it is essential that the barometer and thermometer should exactly correspond at both periods. An increased temperature, or a fall of the barometer, augments the apparent quantity of gas; and a reduced temperature or a higher barometer diminishes its bulk. Another circumstance, an attention to which is indispensable in all accurate experiments, is that the surface of the fluid, by which the gas is confined, should be precisely at the same level within and without the jar. If the fluid be higher within the jar, the contained gas will be under a less pressure than that of the atmosphere, the weight of which is counterpoised by that of the column of fluid within. In mercury, this source of error is of very considerable amount; as any person may be satisfied by pressing down, into quicksilver, a tube partly filled with that fluid, and partly with air, for the volume of the air will gradually decrease, the deeper the tube is immersed.

In experiments on gases, it is not always possible, however, to begin and conclude an experiment at precisely the same temperature, or with the same height of the barometer; or even to bring the mercury within and without the receiver to the same level. In these cases, therefore, calculation becomes necessary; and, with the view of comparing results more readily and accurately, it is usual to reduce quantities of gas to the bulk they would occupy under one given pressure, and at a given temperature. In this country, it is now customary to assume as a standard 30 inches of the barometer, and 60° of Fahrenheit's thermometer; and to bring, to these standards, observations made under other degrees of atmospheric pressure and temperature. The rules, for these corrections, which are sufficiently simple, I shall give in the Appendix.

Of experiments illustrative of the nature of gases 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 gases, 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 gases, viz. that they 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 gases, is chemically combined.

Into a small retort (plate ii. fig. 20. *b*) 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, *c*, having three openings, into one of which the neck of the retort passes, while, from the other, a tube *e* proceeds, which ends in a vessel of water, *f*, of the temperature of the atmosphere. Before closing the apparatus, let a thermometer *d* be included in the balloon, to show the temperature 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 ombined. The caloric, however, is again evolved, when the gas s condensed by water; and, in this experiment, we trace caloric nto combination, and again into the state of uncombined caloric.

For demonstrating the influence of variations of atmospheric pressure on the formation of gases, better experiments cannot be devised than those of Lavoisier—See his Elements, chap. i. 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. This proof is furnished by the experiment described, page 38, in which ether is made to assume alternately an aeriform and liquid state, by removing and restoring the pressure of the atmosphere.

SECTION II.

Oxygen Gas.

I. *Oxygen gas may be procured from various substances.*

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

2. From the red oxide of lead (the common red-lead used by painters), heated either with or without sulphuric acid.

3. From various other oxides, as will be hereafter mentioned.

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

5. From oxygenized muriate of potash, heated in a small glass retort, over an Argand's lamp. The oxygen gas thus produced, is much purer than that obtained in any other mode, especially the last portions, which should be kept separate.

II. This gas has the following properties:

1. *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.

2. *It is rather heavier than common air.*—Mr. Davy stated 100 cubic inches, at 55° Fahrenheit, and 30 inches of the barometer, to weigh 35.06 grains; and at the temperature of 60°, the same quantity would weigh 34.70. Messrs. Allen and Pepys have determined 100 cubic inches to weigh 33.82 grains, the barometer being 30, and thermometer 60°.

2. *All combustible bodies burn in oxygen gas with greatly increased splendour.*

(*a.*) A lighted wax-taper, fixed to an iron wire, and let down into a vessel of this gas, burns with great brilliancy, plate iv. fig. 38. 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.

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* In this as in several other instances, where a gas is said not to be absorbed by water, the assertion is not to be taken strictly, but merely as implying that only a minute and difficultly appreciable portion is absorbed The precise proportion of each gas absorbed by water is stated in the Appendix, in the form of a Table.

(*b.*) A red-hot bit of charcoal, fastened to a copper wire, and immersed in the gas, throws out beautiful sparks.

(*c.*) The light of phosphorus, burnt in this gas, is the brightest that can be in any mode produced. Let the phosphorus be placed in a small hemispherical tin cup, which may be raised by means of the wire-stand, plate ii. fig. 25., two or three inches above the surface of water contained in a broad shallow dish. Fill a bell-shaped receiver, having an open neck at the top, to which a compressed bladder is firmly tied, with oxygen gas; and, as it stands inverted in water, press a circular piece of pasteboard, rather exceeding the jar in diameter, over its mouth. When an assistant has set fire to the phosphorus, cover it instantly with the jar of oxygen gas, retaining the pasteboard in its place, till the jar is immediately over the cup. When this has been skilfully managed, a very small portion only of the gas will escape; and the inflammation of the phosphorus will be extremely brilliant. The expanded gas rises into the flaccid bladder, and is thus prevented from escaping into the room, and proving disagreeable by its suffocating smell.

(*d.*) Substitute, for the phosphorus in Experiment *c*, a small ball formed of turnings of zinc, and in which about a grain of phosphorus is enclosed. Set fire to the phosphorus, and cover it expeditiously with a jar of oxygen. The zinc will be inflamed, and will burn with a beautiful white light. A similar experiment may be made with metallic arsenic, which may be moistened with spirit of turpentine. The filings of various metals may also be inflamed, by placing them in a small cavity, formed in a piece of charcoal, igniting the charcoal, and blowing on the part containing the metal a stream of oxygen gas.

(*e.*) 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 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 (fig. 39.). Fill, also, with oxygen 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 plate iv. fig. 39.). 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, previously to immersion in the gas.

(f.) A little of Homberg's pyrophorus, a substance to be hereafter described, when poured into a bottle full of this gas, immediately flashes like inflamed gunpowder.

III. *During every combustion in oxygen 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 oxygen 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 (plate ii. fig. 25.), 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 oxygen 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 a heated 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.

Those persons who are possessed of a mercurial apparatus may repeat this experiment in a less exceptionable manner. On the surface of the quicksilver let a small hemispherical cup float, made of untinned sheet-iron ; and, in order to keep it from the sides of the jar, it may rest on a wire-stand, shaped like the figure 43, plate iv. Let a jar, the height and diameter of which must be regulated by the size of the mercurial trough, be filled with oxygen gas over water, and be removed, by means of a piece of pasteboard, as before described, to the mercurial bath, inverting it dexterously over the tin cup. If the phosphorus had been previously set on fire, a large quantity of the gas, expanded by the heat, would have escaped, and would have prevented the accurate measurement of the absorption. After drying the surface of the mercury within the jar by blotting paper, a portion of the included gas must, therefore, be removed. This is done by an inverted syphon, one leg of which is to be introduced within the jar before placing it over the mercury ; and the gas will be forced through the open extremity of the other, when the jar is pressed down into the quicksilver. When the proper quantity has been expelled, remove the syphon. The cup, containing the phosphorus, will thus rest on the surface of the quicksilver within the jar, and above the level of the mercury without. The phosphorus is to be inflamed by passing a crooked iron wire, made red hot, through the quicksilver. On the first impression of the heat arising from its combustion, the included gas will be considerably expanded ; but when the phosphorus has ceased to burn, a considerable absorption will be found to have taken place, the amount of which may be measured by ascertaining the height of the quicksilver within the jar, before and after the experiment. The quantity of phosphorus employed should be very small, and should not bear a greater proportion than that of ten grains to each pint of gas ; otherwise the combustion will go on so far as to endanger the breaking of the jar, by the approach of the inflamed phosphorus.

In this process, a white dense vapour is produced, which concretes on the inner surface of the jar in flakes. This substance has strongly acid properties ; and, being formed by the union of oxygen with phosphorus, is termed the phosphoric acid.

The diminution of the volume of oxygen gas, by the combustion of other bodies, may be ascertained in a similar manner. When the substance employed is not easily set on fire, it is proper to enclose, along, and in contact with it, a small bit of phosphorus, the combustion of which excites sufficient heat to inflame iron-turnings, charcoal, &c. In the instance of charcoal, however, though that substance undergoes combustion, no absorption ensues ; because, as will appear in the sequel, the product is a gas, occupying very nearly the same bulk as the oxygen gas submitted to experiment.

IV. *All bodies, by combustion in oxygen gas, acquire an addition to their weight ; and the increase is in proportion to the quantity of gas absorbed.*—To prove this by experiment, requires also a complicated apparatus.

But sufficient evidence of this fact may be obtained by the following very simple experiment. Fill the bowl of a tobacco pipe with iron wire coiled spirally, and of known weight: let the end of the pipe be slipped into a brass tube, which is screwed to a bladder filled with oxygen gas: heat the bowl of the pipe, and its contents, to redness in the fire, and then force through it a stream of oxygen gas from the bladder.—The iron wire will burn; will be rapidly oxydized; and will be found, when weighed, to be considerably heavier than before. When completely oxydized in this mode, 100 parts of iron wire gain an addition of about 30. The qualities of the iron, also, are entirely changed; and it is converted, from a tough metal, into a brittle substance, which may be reduced to powder, is destitute of acid properties, and which is termed an OXIDE.

V. Every substance, capable of union with oxygen, affords, by combustion, either an oxide or an acid; and this difference of the product is the foundation of an arrangement of combustible bodies into the two comprehensive orders of oxydizable and acidifiable bases. Several bodies, however, are susceptible of both these changes; and yield, by combustion, compounds possessing the properties of oxides or of acids, according to the quantity of oxygen combined with them; the highest state of oxygenation imparting the characters of an acid, and an inferior degree converting them into oxides.

VI. *Oxygen 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 oxygen gas, than in one of atmospherical air of the same dimensions.

VII. *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 be in part 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 oxygen gas, and shaking it up.

SECTION III.

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 any of the following manners: 1. Mix equal weights of iron filings and sulphur into a paste with water, and place the mixture, in a proper vessel, over water, supported on a

stand: 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 3-4ths of its original bulk will 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.

2. 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 firmly placed over the mouth of the bottle; and, when removed, the mouth of the bottle must be immersed in a cup full of the same solution, which will supply the place of the absorbed air.

3. Atmospheric air, also, in which phosphorus has burned out affords, when time has been allowed for the condensation of the phosphoric acid, tolerably pure azotic gas.

This gas has the following properties:

1. It is not absorbed by water.

2. *It is a little lighter than atmospheric air*, 100 cubic inches being found by Mr. Davy to weigh 30.04 grains under a pressure of 30 inches, and at the temperature of 55° Fah^{t}. At 60° Fah^{t} 100 inches weigh, therefore, 29.73 grains.

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

Even phosphorus, in a state of active inflammation, is immediately extinguished when immersed in azotic gas. This is best shown by placing the burning phosphorus in a tin cup, raised by a stand above the surface of the water, and quickly inverting over it a jar filled with azotic gas.

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

5. When mixed with pure oxygen gas, in the proportion of 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 four parts of azotic gas with one of oxygen gas, and immersing in the mixture, a lighted taper. The taper will burn as in atmospherical air.

SECTION IV.

Atmospheric Air.

The air of our atmosphere, it appears, therefore, from the foregoing facts, is a mixture, or possibly a combination, of two different gases, viz. oxygen 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 oxygen gas which it contains; and, when this is exhausted, air is no longer capable of supporting combustion*. The abstraction of its oxygen gas from the air will be rendered apparent by the following experiments:

I. Burn a little sulphur or phosphorus, in the manner described, Sect. II., substituting, for oxygen 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.

The phosphorus, however, will have absorbed the whole of the oxygen gas contained in the air submitted to experiment; and hence it may be employed for measuring the quantity of oxygen gas in a given bulk of atmospherical air. This may be accomplished, either by its slow or rapid combustion. Berthollet proposes (34. An. Ch. 78.) to expose a cylinder of phosphorus, fastened to a glass rod, in a narrow glass vessel, graduated into equal parts, and standing full of air over water. The phosphorus immediately begins to act on the included air; and in six or eight hours its effect is completed. The residuary azotic gas has its bulk enlarged about one-fortieth, by absorbing a little phosphorus; and, for this, allowance must be made in measuring the diminution. In the eudiometer of Seguin, the rapid combustion of phosphorus is employed with the same view. A glass tube, open at one end only, about an inch in diameter, and eight or ten high, is filled with, and inverted in, mercury. A small bit of phosphorus, dried with blotting paper, is then introduced, and, by its inferior specific gravity, rises to the top of the tube, where it is melted, by bringing a red hot poker near to the outer surface of the glass. When the phosphorus is liquefied, a measured portion of the air to be examined is ad-

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

mitted, by a little at once, into the tube. The phosphorus inflames at each addition, and the mercury rises. When all the air under examination has been added, the red-hot poker is again applied to ensure the completion of the process, and the residuary gas is transferred into a graduated measure, where its bulk is carefully ascertained. In this instance, about one-fortieth the volume of the residuary gas is to be deducted from the apparent quantity of azotic gas, because, in this case also, a small portion of phosphorus is dissolved by the latter, and occasions a trifling expansion. With this deduction, atmospheric air loses pretty accurately 21 parts out of each 100 ; and contains, therefore, 21 *per cent.* of oxygen, and 79 of azote by measure.*

II. The inferior fitness of atmospherical air, to that of oxygen gas, for supporting combustion, may be shown, also, by a comparative experiment with two candles. Provide two circular pieces of lead, three inches diameter, and half an inch thick, from the centre of each of which proceeds a perpendicular iron wire, six or eight inches high ; to the end of both wires fasten a piece of wax taper. Provide also two jars, each two inches diameter, and twelve long, and having a neck at the top, with a compressed bladder tied upon it. Fill one of the jars, leaving the bladder empty, with oxygen gas ; and, at the same instant, with the aid of an assistant, invert both jars over the burning candles, keeping the oxygen gas in its place till the jar is inverted, by a piece of pasteboard. In the common air, the candle will soon be extinguished ; but that confined in oxygen gas will burn with much greater splendour, and will continue burning long after the other is extinguished. On the first impression of the flame, a quantity of expanded gas will rise into each bladder, which is to be pressed out at the close of the experiment, in order that the absorption may be compared in both cases. The diminution in the jar of oxygen gas will be found greatly to exceed that of the common air.

III. Take two tubes, each a few inches long, closed at one end, and divided into 100 aliquot parts. Fill the one with atmospherical air, the other with oxygen gas, and invert them in two separate cups filled with a solution of sulphuret of potash. The sulphuret will ascend gradually within the tube of common air, till, after a few days, only about four-fifths of its original

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* Various other methods of analyzing atmospherical air will be described in the course of the work. References to them may be found in the Index article Eudiometer.

volume will remain; but, in that containing oxygen, 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 potash has the property of absorbing oxygen, but not azote. It therefore acts on atmospheric air only as long as any oxygen gas remains, and may be employed as a means of ascertaining the quantity of this gas in the atmosphere at different 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. p. 268; or Tilloch's Philosophical magazine, vol. iii. p. 171.) But an apparatus, of much greater simplicity, and facility of application, is that of Professor Hope of Edinburgh, announced in Nicholson's Journal, 8vo. iv. 210. It consists of a small bottle, of the capacity of 20 or 24 drachms (fig. 28. pl. ii.), destined to contain the eudiometric liquid, and having a small stopper at *b*. Into the neck of the bottle a tube is accurately fitted, by grinding, which holds precisely a cubic inch, and is divided into 100 equal parts. To use the apparatus, the bottle is first filled with the liquid employed, which is best prepared by boiling a mixture of quicklime and sulphur with water, filtering the solution, and agitating it for some time in a bottle half filled with common air. The tube, filled with the gas under examination (or with atmospherical air, when the quality of this compound is to be ascertained), is next to be put into its place; and, on inverting the instrument, the gas ascends into the bottle, where it is brought extensively into contact with the liquid, by brisk agitation. An absorption ensues; and, to supply its place, the stopper *b* is opened under water, a quantity of which rushes into the bottle. The stopper is replaced under water; the agitation renewed; and these operations are performed alternately, till no farther diminution takes place. The tube *a* is then withdrawn, the neck of the bottle being under water, and is held inverted in water for a few minutes; at the close of which the diminution will be apparent. Its amount may be measured by the graduated scale engraved on the tube.

IV. *Atmospheric air ministers to the support of animal life, only in consequence of the oxygen 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 to

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* Other Eudiometers will be described hereafter.

12 *per cent.* It proves fatal to animals, however, long before this purer portion is wholly exhausted; and hence it appears, that a considerable portion of oxygen 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.

V. *Atmospheric air is diminished in volume by animal respiration.*—This may be shown by repeating a very simple experiment, originally contrived by Mayow. He confined a mouse in a small glass jar, and tied the jar over, quickly and firmly, with moistened bladder. The heat of the animal first expanded the air, and rendered the bladder convex outwards; but when the animal had died, and had become cold, the bladder exhibited a hollow surface, proving that the air within was diminished in its bulk.

The exact amount of the diminution may be shown, by confining a mouse, over water, in a graduated jar, furnished with a stop-cock, and containing common air. As the heat of the animal, however, would occasion the expulsion of part of the air, it is expedient, on first depressing the jar into water, to open the cock, through which a part of the air will escape: the cock is then to be shut, and the height of the water within to be accurately noted. At first, the level will be depressed, in consequence of the expansion of the air by the warmth of the animal; but, after its death, a considerable diminution will be observed.

VI. The weight of a given volume of atmospheric air, at 60° Faht and 30 inches barometer, is said by Mr. Kirwan to be 30.92 grains. Mr. Davy states it, when under the same pressure, but at 55° Faht, to be 31.10 grains, from which may be deduced that, with the temperature and pressure assumed by Mr. Kirwan, 100 inches would weigh 30.78 grains.

SECTION V.

Hydrogen Gas.

I. *To procure hydrogen 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; or (what is still better) on zinc, granulated by pouring it melted into cold water, and contained in a gas bottle or small retort. An effervescence will ensue, and the escaping gas may be collected in the usual manner.

II. This gas has the following properties :

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

2. *It is inflamable.* This may be shown by the following experiments :

(*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 hydrogen 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.

Persons, who are provided with the jars represented plate ii. fig. 22. *a*, may screw to the cock a brass pipe with a small aperture. On pressing the jar, filled with hydrogen gas, into the water, and opening the cock, the gas will be forced out in a stream, which may be set on fire. On this principle are founded the artificial fire-works without smell or smoke. They consist of pipes, having variously sized apertures, some of which have a rotatory motion ; but their precise construction it is impossible to describe, without very tedious details.

(*c.*) In a strong bottle, capable of holding about four ounces of water, mix equal parts of common air and hydrogen gas. On applying a lighted candle, the mixture will burn, not silently, as in experiment (*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 be burst*.

(*d.*) The same experiment may be repeated with oxygen gas, instead of atmospherical air; changing the proportions, and mixing only one part of oxgen gas with two of hydrogen. 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 twelve inches long, closed at one end, (plate ii. fig. 28.) 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. An apparatus, serving the same purpose, and much more easily constructed, may be formed by hermetically sealing a piece of brass wire, or still better platina wire, into the end of a glass tube, (fig. 29.) With this conductor, an interrupted circuit may be formed, by introducing into the tube a longer wire, one end of which terminates one-tenth of an inch from the upper one, while the other extends beyond the aperture of the tube. Into this tube, standing over water, pass about half a cubic inch of a mixture of hydrogen and oxygen gases, 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 gases. An immediate explosion will take place; after which the gases, if pure, and in the proper proportion, will be found to have disappeared entirely.

If atmospherical air be employed, a diminution, though not equal in amount, will be produced by the union of the hydrogen with the oxygen gas contained in the air; and, if a sufficient quantity of hydrogen gas be employed, the whole of the atmospheric oxygen will thus be removed. On this principle is founded the EUDIOMETER OF VOLTA, which may be constructed, by graduating either of the tubes already described, into equal parts. If, in one of these tubes, we mix 300 parts of common air, and 200 of pure hydrogen gas, there will remain, after the explosion excited by passing an electric spark between the two wires, about 305 measures. There will, therefore, have

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

been a diminution of 195 measures, of which pretty exactly one-third may be estimated to be pure oxygen. In this instance, therefore, 65 of oxygen have been lost by 300 of air, or 21 and a fraction *per cent.*

The general rule for ascertaining the purity of air by hydrogen gas, may be stated as follows: Add to three measures of the air under examination, two measures of pure hydrogen gas; inflame the mixture by electricity; observe the diminution when the vessel has cooled; and, dividing its amount by three, we obtain pretty nearly the quantity of oxygen gas which has been condensed.

(*f.*) The diminution of hydrogen and oxygen gases, by the union of their bases, may be shown also by their slow combustion. Fill a tall jar with oxygen 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, (plate iv. fig. 41.) 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 oxygen 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.

The same experiment may be more accurately and elegantly made, by substituting for the bladder, a small gazometer, containing a measured quantity of hydrogen gas. Let the bent pipe be screwed on the cock of the gazometer; and over its open end, placed perpendicularly, invert a jar of oxygen gas. This jar must be provided at the top with a metallic conductor, screwed into a brass cap, as represented in fig. 41.; which shows also the level of the water within the jar, attained by means of a syphon. After noting the height of the water within, let a rapid succession of electric sparks be passed between the two conductors; and, on opening the cock at this instant, the stream of oxygen gas will be inflamed. The end of the pipe must then be so far depressed, that the cement of the brass cap may not be melted by the flame; and the outer surface of the top of the vessel should be kept cool. When the gas is first lighted, the oxygen gas will be suddenly expanded; but, presently, a rapid diminution will go on, till the water rises above the end of the pipe and extinguishes the flame. If pure oxygen gas be employed, it will be found, after the experiment, uninjured in its quality, and will support the combustion of burning bodies as well as before.

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

(*g.*) When a stream of hydrogen gas is burned under a tube, eighteen or twenty-four inches long, a musical sound is produced. The experiment may be made in the following manner:

Into a glass bottle are put iron filings and sulphuric acid, diluted with five or six parts of water; and a cork is fitted into the neck, through which a glass tube is passed, having its upper extremity drawn out to a capillary bore. By setting fire to the hydrogen gas*, which escapes from this extremity, a continued current or jet of flame is produced, which is allowed to pass into a tube either of glass, earthen-ware, or metal. If the tube be not too large, the flame becomes smaller as it is depressed; and when the tube covers the flame to a considerable depth, very clear sounds are produced. But, on the contrary, if the tube be too narrow, the flame will be extinguished; and, in proportion as the tube is enlarged, the sound diminishes: so that there is a certain limit at which it totally ceases. The same happens when the tube is too long. The sounds may be raised at pleasure, by either using tubes of various figures or dimensions, or made of different substances: (see Nicholson's Journal, 8vo. i. 129., and iv. 23.).

(*h.*) In a memoir lately read to the National Institute of France, M. Biot announces the important fact, that a mixture of hydrogen and oxygen gases may be made to explode by mechanical compression. A mixture of these two gases was introduc-

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* The gas must not be inflamed, till it has been produced for some time, and has expelled all the common air of the bottle; otherwise an explosion will happen, and the bottle will be burst, with some danger to the operator.

ed into a strong metallic syringe, furnished with a glass bottom, and a sudden stroke given to the piston. An extremely brilliant light appeared, accompanied with a loud detonation; and the glass bottom was forcibly driven out. The repetition of this experiment, it is obvious, must be attended with considerable difficulty and danger: (see Nicholson's Journal, xii. 212.)

1. The combustion of hydrogen and oxygen gas is successfully applied to the purpose of exciting an intense heat by the blow-pipe. The peculiar construction of the apparatus cannot be understood without a plate, which may be seen in the *Annales de Chimie.* It may be sufficient here to state, that the gases are contained each in a separate gas-holder; that they are expelled by the pressure of a column of water obtained by lengthening the pipe *b*, fig. 36.; and that their mixture does not take place, till they nearly reach the aperture of the pipe, at the extremity of which they are inflamed. This last precaution is of considerable importance, because a violent and dangerous explosion would otherwise happen. To guard the more effectually against this accident, it is advisable to affix a valve, opening outwards, in the pipe proceeding from each gas-holder, just before the junction of the two.

2. *Hydrogen gas has an unpleasant smell.*

3. *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.

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

5. *It is considerably lighter than atmospheric air.*—One hundred cubic inches, the barometer being 30 inches, and the thermometer 60°, weigh, according to Kirwan, 2.613 grains; according to Lavoisier, 2.372 grains; and according to Fourcroy, Vauquelin, and Seguin, 2.75 grains.

(*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 stopcock; 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.

CHAPTER VI.

OF THE COMPOSITION, DECOMPOSITION, AND PROPERTIES OF WATER.

SECTION I.

Synthesis, or Composition, of Water.

In chap. v. sect. v. it was stated, that oxygen and hydrogen gases, 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, by means of the detonating tube, (plate ii. fig. 28.) 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 gases, but only of their bases; for the light and caloric, which constituted the gases, 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 gases; 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.

I. Fill, with hydrogen gas, a bladder, furnished with a stopcock and bent pipe (fig. 41. *e*), as in the last chapter. Then pour into a shallow earthen 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 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.

II. 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 rarefied and vitiated air will ascend through the 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.

III. 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; and also in pl. iv. of this work, fig. 33.

In using this apparatus, however, instead of two glass receivers for the oxygen and hydrogen gases, standing inverted in a trough of water, I employ a couple of gazometers; and with this alteration, the experiment is more easily managed, as well as more striking. The apparatus, thus modified, consists of a large glass receiver or bottle *a* (plate iv. fig. 34.), with an opening at the bottom, into which is cemented a piece of brass, perforated with two holes. This brass piece is represented of a larger size in fig. 33.; the aperture *a* conveying the oxygen gas, and *b* the hydrogen. Before commencing the experiment, the cock *c*, fig. 34. is screwed, by means of a collar-joint*, to the cock *b* of the gazometer, fig. 35. containing oxygen gas; and to the cock *d*, by the same means, is affixed another gazometer, filled

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* See plate v. fig. 47; and the corresponding description of the structure of this joint, in the explanation of the plates at the end of the work.

with hydrogen gas. When it is intended to ascertain, accurately, the proportions of gases consumed, the receiver *a*, previously weighed, is first exhausted by an air-pump, with which it may be connected by the female screw at *c*. The quantity of common air left in the receiver may be determined, by enclosing a gage within it. If the additional expense be not deemed an objection, it is advisable, that after exhausting the receiver, oxygen gas should be admitted; its contents be exhausted a second time; and again renewed by fresh oxygen from the gazometer, the quantity of which may be observed by the graduated scale. The receiver being thus filled with oxygen gas, and accurately closed by a cock at *c*, a succession of sparks is to be passed, from the prime conductor of an electrical machine, between the platina knob of the bent wire within the receiver, and the point of the brass cone. While the sparks are transmitted, the cock *d* is to be opened. A stream of hydrogen gas will immediately issue from the aperture at the point of the cone, and will be inflamed by the electric spark, as represented fig. 33. The cock *e* is now to be opened, and the size of the flame of hydrogen gas moderated by partly shutting the cock *d*. As the volume of hydrogen gas consumed is double that of the oxygen; and the pipe, which transmits it, is of less diameter than that conveying the latter, about twice the pressure is required to expel the hydrogen. This is given, by lessening, in that proportion, the weight of the counterpoises (*ee*, fig. 35.) of the gazometer containing hydrogen.

During the combustion, the moveable vessel *c*, fig. 35. of each gazometer descends; and, by observing the graduated scales, it will be seen that the hydrogen vessel falls twice as quick as that which holds the oxygen gas. It is necessary to keep the receiver *a* cool by means of wet cloths; and, when this is done, the water, which is produced, will form into drops on the inside of the receiver, and collect at the bottom. At the conclusion of the experiment, the receiver is to be again weighed, and the increase noted. The quantity of gases consumed is to be observed, and their actual weight computed, by means of the Table given in the Appendix. It will be found, that the weight of water produced is very nearly equal to that of the two gases expended; that is to say, excluding decimals, for every hundred grains of water in the receiver, eighty-five grains of oxygen gas, and fifteen grains of hydrogen gas, will have disappeared.

IV. By firing repeated portions of a mixture of oxygen and hydrogen gases over mercury, a sensible quantity of water will at last be produced.

SECTION II.

Analysis, or Decomposition, of Water.

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.

I. Of the first kind are the following:

1. 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 pneumatic cistern. Let the barrel be placed horizontally (or rather with that end, to which the retort is fixed, a little elevated) in a furnace, which has two openings in its body opposite to each other. (Plate iv. fig. 40.) 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.

2. 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 (fig. 40. *e*), and to the weight of the gases 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 gases, by volume, required to form water, is about two of hydrogen to one of oxygen gas.

3. 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.

4. 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, or 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 oxygen 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.

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

1. 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 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 twelve inches long, one of the ends of which is sealed hermetically, a gold 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 hy-

drogen and oxygen gases, in a state of admixture, are the only ones that are capable of being inflamed 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 gases arise from decomposed water.

2. 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 Philosophical Transactions for 1797, or in Nicholson's Journal, vols. i. and ii. 4to.

3. 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 past century. It is constructed in the following manner:

Procure, at a brazier's or coppersmith's, thirty, forty, or fifty 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 woolen 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 twenty or thirty, 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, or zinc and copper, plates may also be more commodiously arranged in a mahogany trough. (Plate iv. fig. 37.) 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. They may be purchased, ready made, of various sizes and powers, at the shops of philosophical instrument-makers.

With this apparatus, the decomposition of water is effected with the utmost facility. Take a narrow glass tube, three or four 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 (see fig. 37. *b*.) 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 oxydized by water, as gold, for example, we obtain a mixture of hydrogen and oxygen gases, as in the experiment of Messrs. Dieman and Van Troostwyk.

In the latter case, a very evident difference may be observed in the quantity of gas extricated from the two wires. That connected with the zinc end (which, for the sake of distinction, may be called the zinc-wire) is much less in quantity, than what issues from the copper-wire. By a slight variation in the apparatus, we may obtain these two gases separately*, viz. by placing the two wires in separate legs of a syphon, as represented in Nicholson's Journal, 4to. vol. iv. plate 21. On examining the gases, that evolved by the zinc-wire will be found to be oxygen, and that from the copper-wire hydrogen, in the proportion, by measure, of one of the former to two of the latter.

In Nicholson's Journal, 4to. vols. iv. and v. 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. The recent and very important experiments of Mr. Davy (Phil. Trans. 1807. Part i.) have shown that Galvanic electricity may be employed as an agent in the decomposition of almost every compounded substance. The explanation, however, of these agencies implies a knowledge of a large class of substances, with which the reader may at present be supposed to be unacquainted; and is not, indeed, much connected with the elementary doctrines of chemistry. [See additions at the end.]

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* The separation, however, is by no means complete.

SECTION III.

Properties and Effects of Water.*

I. *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. The same fact may also be exhibited, by filling a barometer tube, about thirty-two inches long, sealed at one end, with quicksilver, except about four inches, and the remainder with water. On inverting the open end of the tube in quicksilver, bubbles of air will be seen, in a short time, to rise from the water.

II. *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 potash (not crystallized, but the common salt of tartar). In a few days it will have become moist, or *deliquiated.* On the same principle, water exposed to the air, in a shallow vessel, disappears, being dissolved by the atmosphere.

III. *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 chap. ii.

IV. *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 chap. iii. sect. 2. 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.

V. *During the solution of salts in water, a quantity of air is disengaged.*—This air was partly contained mechanically in the

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

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, agreeable to the principle laid down, chap. ii. 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.

VI. *During the solution of bodies, the bulk of water changes.*—Take a glass globe, furnished with a long narrow neck (commonly termed a mattrass, see fig. 4.), 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 mattras. The salt will dissolve ; air will be set at liberty ; and, during the solution, the water will sink considerably below its level. The 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 Landaff observed, 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.

VII. *Water has its solvent power increased, by diminishing the pressure of the atmosphere.*—Into a Florence flask, put half 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, chap. iii. sect. 2. vi. 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 reverse of that in which cold is produced, or caloric absorbed, during the solution of salts.

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

It is remarkable, that this enlargement of the bulk of water begins long before its temperature has descended to the freezing point, viz. at about 40° Fahrenheit. Let a thermometer bulb, and part of its tube, having a wide bore, be filled with water, tinged with a little litmus, which may be introduced by the same means as those already directed for filling with quicksilver. Immerse the thermometer in water of the temperature of 40° ; and, when the included water may be supposed to have attained the same degree of heat, remove the instrument successively into water of the temperature of 36° and 32°. At each immersion, the water will rise in the tube. Bring its temperature again to 40°, and it will descend to the same point as before. Place it in water of 50°, and it will again be expanded. Precisely similar effects, therefore, appear to result, in these experiments, from two opposite causes ; for the bulk of water is alike increased by reducing or raising its temperature. It is contended, however, by Mr. Dalton, that, in the apparent expansion by a lower temperature, there is a deception, arising from the contraction of the glass, which must lessen the capacity of the bulb, and force the water up the stem. The question is not yet decided ; and is still contested by Mr. Dalton against the experiments of Count Rumford and of Dr. Hope. The former philosopher now contends, that water is of the greatest density at 36° of Fahrenheit, or 4° above its freezing point.

CHAPTER VII.

ALKALIS.

General Qualities.

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

(*a.*) The alkalis 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.

(*d.*) They corrode woolen cloth ; and, if the solution be sufficiently strong, reduce it to the form of a jelly.

(*e.*) They are readily soluble in water.

SECTION I.

Pure Potash and Pure Soda. [See additions at the end.]

To prepare pure potash, dissolve any quantity of American or Dantzic pearlash in twice its weight of boiling water, and add the solution, 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 alkali, either by filtering or by 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 alkali, 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, substituting the carbonate of soda for the pearlash.

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* The figure of an alembic may be seen in plate i. fig. 2.

These alkalis 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 alkalis be employed; but the crystallized alkalis generate cold, when dissolved.

(*c.*) They are not volatilized by a moderate heat, and hence have been called fixed alkalis.

SECTION II.

Pure Ammonia.

I. 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*.

II. 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. Before, however, a candle is extinguished, by immersion in this gas, the flame is enlarged, by the addition of another, of a pale yellow colour, which descends from the mouth of the jar to the bottom. If the flame of the candle be only in part immersed in the gas, this yellowish flame rises a few lines above the other.

(*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. One hundred cubic inches of this gas weigh 18.05 grains, barometer 30, thermometer 55°; or 17.86 grains, the pressure being the same and the thermometer 60°.

(*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. From Mr. Davy's experiments, it appears that 100 grains of water absorb 34 grains of ammoniacal gas, or 190 cubic inches. Therefore a cubic inch of water takes up 475 cubic inches of the gas.

Alcohol, also, absorbs several times its bulk, and affords a solution of ammonia in alcohol, which possesses the strong smell and other properties of the gas.

(*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. The method of effecting this impregnation will be described herereafter; and processes will be given for obtaining the solution of ammonia in considerable quantity, which cannot conveniently be accomplished by the process described in experiment *e*. This solution again yields its gas on applying heat. (see i. *b.*)

(*g.*) This gas is decomposed by electricity.—Provide a tube furnished with two conductors (fig. 28.), 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. Admit to this gas about one-fourth its bulk of oxygen gas of known purity, and pass an electric spark through the mixture. A detonation will take place, which will be followed by a considerable diminution of volume. Of this absorption, two-thirds are owing to the condensation of hydrogen gas. There is still, however, a considerable residue of gas, which most probably contains a redundancy of oxygen. This excess of oxygen may be absorbed by the sulphuret of lime, and the remainder will be found to be azotic gas. Hence it appears, that ammonia yields, when submitted to electricity, hydrogen and azotic gases; and is therefore a compound of hydrogen and azote. The proportion in which these gases are obtained, is about 35 of the former to 105 of the latter; and, calculating from their known gravity, it is inferred, that 100 parts of pure gaseous ammonia are composed, by weight, of 20 hydrogen and 80 azote.

(*h.*) The decomposition of ammonia may also be easily shown, by galvanizing, with the apparatus described page 77, a saturated solution of ammonia in water. In this experiment a considerable quantity of gas is produced. Expose it over a solution of sulphuret of potash. A small part of it, being oxygen gas, will disappear. The remainder consists of hydrogen and azotic gases.

CHAPTER VIII.

EARTHS. [See additions at the end.]

THE term earth was, till lately, employed to denote "a tasteless, inodorous, dry, brittle, and uninflammable substance, not more than five times heavier than water." This definition, however, was rendered imperfect by the discovery, that certain earths have a strong taste, and are readily soluble in water, which yet possess the other characters of earthy bodies. Some of the earths where therefore removed from this class, and arranged among the alkalis. The classification, however, which appears to me most eligible, is that which divides them into *earths* simply, and *alkaline earths;* the latter partaking of the characters both of earths and alkalis. The alkaline earths are Barytes, Strontites, Lime, and Magnesia. The earths are Silex, Alumine, Zircon, Glucine, and Yttria*.

The most important properties of the earths are those depending on their relation to acids, a class of bodies, which will be described in the sequel. In this chapter, therefore, I shall describe only the effects produced on them by caloric; by water; by alkalis; and the results of their combinations with each other.

SECTION I.

Barytes.

Barytes may be obtained in a state of purity, by the calcination of its carbonate of nitrate, in a manner which will be hereafter described. (See chap. x. sect. ii. art. iv.) It exhibits, when pure, the following properties.

I. Barytes, in a pure form, has a sharp caustic taste; changes vegetable blue colours to green; and serves as the intermedium between oil and water. In these respects, it bears a strong resemblance to alkalis.

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* The Augustine of Tromsdorff has been shown, by Berthollet, to be merely Phosphate of Lime. Nich. Journ. 8vo. vii. 117.

II. When exposed to the flame of the blow-pipe on charcoal, it melts; boils violently; and forms small globules, which sink into the charcoal. If perfectly free from water, however, it is infusible.

III. If a small quantity of water be added to recently prepared barytes, it is absorbed with great rapidity; prodigious heat is excited; and the water is completely solidified, a sort of hard cement being obtained. A little more water converts this mass into a light bulky powder; and, when completely covered with water, the barytes is dissolved. Boiling water should be employed for this purpose; unless a sufficient temperature has been produced, by the sudden addition of the whole quantity necessary for solution.

IV. When the solution, prepared with boiling water, is allowed to cool slowly, it shoots into regular chrystals. These have the form of flattened hexagonal prisms, having two broad sides, with two intervening narrow ones; and terminated, at each end, by a quadrangular pyramid.

V. The crystals are so soluble, as to be taken up, when heated, merely by their own water of crystallization. When exposed to a stronger heat, they swell, foam, and leave a dry white powder, amounting to about 47 parts from 100 of the crystals. This again combines with water with great heat and violence. At 60° of Fahrenheit, an ounce measure of water dissolves only 25 grains of the crystals, i. e. they require for solution, 17½ times their weight of water. Exposed to the atmosphere, they effloresce, and become pulverulent.

VI. When added to spirit of wine, and heated in a spoon over a lamp, they communicate a yellowish colour to its flame.

VII. The specific gravity of this earth, according to Fourcroy, is 4, but Hassenfratz states it at only 2.374. The former account, however, is the more probable. All its combinations have considerable specific gravity; and hence its name is derived, viz. from the Greek word ϐαϱύς, signifying heavy.

VIII. Barytes does not unite with any of the alkalis.

SECTION II.

Strontites.

I. Strontites (called also Strontia, from Strontian in Scotland, the place where it was first discovered) resembles barytes in many of its properties; and all that is included in the first three paragraphs of the last section may be applied, also, to this earth.

II. Like barytes, strontites is readily soluble in boiling water; and the solution, on cooling, affords regular crystals; but the shape of these differs considerably from that of barytic crystals. The crystals of strontites are thin quadrangular plates; sometimes square, oftener parallelograms; not exceeding in length, and not reaching in breadth, a quarter of an inch. Sometimes their edges are plain, but they oftener consist of two facets, meeting together, and forming an angle like the roof of a house. They adhere to each other in such a manner as to form a thin plate, of an inch or more in length, and half an inch in breadth. Sometimes they assume a cubic form.

III. These crystals undergo, by the action of heat, much the same changes as those of barytes; and leave only about 32 per cent. of the dry earth. One part of the crystals requires about 51½ of water at the temperature of 60° for solution, but boiling water takes up half its weight.

IV. Boiling alcohol, with the addition of these crystals, burns with a blood-red flame.

V. Strontites does not combine with alkalis. Barytes has no affinity for it; for no precipitation ensues, on mixing the watery solutions of the two earths.

From the preceding enumeration of its characters, it appears that strontites differs from barytes, in the different form of its crystals, which contain also more combined water, and are less soluble than those of barytes; and in affording, with alcohol, a flame of different colour. These distinctions were deduced by Dr. Hope, from his excellent series of experiments on these two earths.[f] (See Edinb. Trans. vol. iv.) Other circumstances of distinction will be stated hereafter.

SECTION III.

Lime.

I. *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.

II. *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 sufficient to set fire to some inflammable bodies; and when a large quantity of lime is suddenly slaked in a dark place, even light, according to Pelletier, is sometimes evolved. The caloric, which is thus set at liberty, is doubtless that contained in the water, and essential to its fluidity. By combination with lime, water passes to a solid state, and probably even to a state of much greater solidity than that of ice. Hence, during this change, it evolves more caloric than during conversion into ice; and hence even ice itself, when mixed with quicklime, in the proportion of one to two, enters into combination, and has its temperature raised to 212°. When a sufficient quantity of water has been added to reduce lime into a thin paste, this is called *milk* or *cream of lime*.

Lime is, in some degree, convertible into vapour by combination with water. When a piece of moistened paper, stained with the juice of the violet, is held in the steam, which arises from lime suddenly slaked, its colour is changed from blue to green. Hence the smell which is perceived during the slaking of lime.

(*b.*) Lime absorbs moisture from the atmosphere, and falls gradually into powder.

(*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 strongly 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.

(*d.*) Lime does not combine, in any notable proportion, with the alkalis or earths already described.

SECTION IV.

Magnesia.

Magnesia possesses the properties of an alkali, but in a considerably less degree than any of the foregoing earths. Its characters are as follow:

I. When perfectly pure, it is entirely destitute of taste or smell.

II. No heat is excited by the affusion of water, and only a very small proportion, not exceeding 1-2000 its weight, of the earth is dissolved. Magnesia appears, however, to have some affinity for water; for when moistened, and afterwards dried, its weight is found increased in the proportion of 118 to 100.

III. Magnesia changes to green the blue colour of the violet; but the watery solution of magnesia, when filtered, does not produce a similar effect. In this respect, it differs from lime.

IV. It is not dissolved by liquid alkalis, nor by alkaline earths; and in the dry way, it has no affinity for barytes or strontites.

SECTION V.

Silex.

I. 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. The materials must bear only a small proportion to the capacity of the crucible; and the heat must at first be very moderate, and slowly increased. Even with this precaution, the mass, on entering into fusion, will be apt to overflow; and must be pressed down as it rises, by an iron rod. When this effervescence has ceased, let the heat be considerably raised, so that the materials may be in perfect fusion during half an hour, and pour the melted mass on a copper or iron dish. We shall thus obtain a compound of alkali and siliceous earth. Dissolve this in water, filter 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.

Silex, obtained by this process, though pure enough for the following experiments, may still contain a portion of alumine. To separate the latter earth, boil the precipitate with diluted sulphuric acid, to which a little sulphate of potash may be added. The alumine will thus be dissolved; and the silex may be freed from the solution by repeated washings with water.

II. 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 insoluble in water. Yet, when fresh precipitated, water has the property of retaining in solution about one-thousandth of its weight*. That silex, however, is dissolved in water by processes of nature, can scarcely be doubted, when it is considered, that it is found, in considerable quantities, in a chrystalized form.

(*d.*) It is not acted on by any acid, except the fluoric.

(*e.*) When prepared in the foregoing manner, and very minutely divided, silex is taken up by a solution of pure potash, or of soda, but not by ammonia. In the aggregated state of flints, however, it is perfectly insoluble in this way by alkaline solutions, an excellent illustration of the principle laid down, chap. ii. 3.

(*f.*) 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 it 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.

(*g.*) With a larger proportion of alkali, as three or four parts to one of silex, this earth affords a compound called, by Dr. Black, *silicated alkali.* This compound, formed by the process which has been just described, 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 alkali was formerly termed *liquor silicum*, or *liquor of flints.* Acids seize the alkali, and precipitate the silex, which is even separated by mere exposure to the atmosphere, in consequence of the absorption of carbonic acid by the alkali.

(*h.*) Barytes, or strontites, and silex combine together, in a manner similar to the union of this earth with alkalis; but the combination has not been applied to any useful purpose.

(*i.*) When the solution of silex in potash is mingled with one of barytes, of strontites, or of lime in water, or of alumine in alkali, a precipitation ensues. Hence silex may be inferred to have an affinity for all these earths, in the humid way.

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* See Klaproth's Contributions, vol. i. p. 399, 400.

SECTION VI.

Alumine.

I. *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 re-dissolved 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.)

II. Alumine has the following properties :

1. It is destitute of taste and smell.

2. When moistened with water, it forms a cohesive and ductile mass, susceptible of being kneaded into a regular form. It is not soluble in water ; but retains a considerable quantity.

3 It does not affect blue vegetable colours.

4. It is dissolved by the liquid fixed alkalis, and is precipitated by acids unchanged. In ammonia, it is very sparingly soluble. It is not soluble in alkaline carbonates.

5. Barytes and strontites combine with alumine, both by fusion and in the humid way. In the first case, the result is a greenish or blueish coloured mass. In the second, two compounds are formed. The first, containing an excess of alumine, is in the state of an insoluble powder ; the other, having an excess of the alkaline earth, remains in solution. Alumine may be united, by fusion, with the fixed alkalis, and with most of the earths.

6. Alumine, as will be afterward shown, has a strong affinity for colouring matter.

7. Alumine has the property of shrinking considerably in bulk, when exposed to heat, and its contraction is in proportion to the intensity of the heat applied. On this property is founded the *pyrometer of Wedgewood*, which measures high degrees of heat, by the amount of the contraction of regularly shaped pieces of china clay. The pieces of clay are small cylinders, half an inch in diameter, flattened on the under surface, and baked in a low red-heat. The contraction of these pieces is measured, by putting them between two fixed rulers of brass or porcelain, twenty-four inches long, half an inch distant from each other at one end, and three-tenths of an inch at the other. The rulers are divided into 240 equal parts, called degrees, which commence at the wider end ; and each of which is equal to 130° of Fahrenheit.

When the clay piece is fixed in its place, before exposure to heat, it is stationary at the first degree, which indicates about 1077° of Fahrenheit. After being strongly heated, in a small case which defends it from the fuel, its bulk is diminished, and it slides down, between the converging rulers, till stopped by their approach. The number on the graduated scale, opposite to the upper end of the piece, indicates the degree of heat to which it has been exposed. In the Appendix, rules may be found for reducing the degrees of Wedgewood's pyrometer to those of Fahrenheit's thermometer.

SECTION VII.

Zircon.

I. This earth was discovered by Klaproth in the year 1789, in a precious stone from the island of Ceylon, called Jargon or Zircon ; and has since been detected in the hyacinth. It may be obtained by the following process :

Reduce the hyacinth to fine powder, which may be done in an agate mortar, after previously igniting the stone, and plunging it into cold water, to render it brittle. Mix the powder with nine times its weight of pure potash ; and project it, by a spoonful at once, into a red-hot crucible, taking care not to add fresh portions till the former ones are melted. When the whole is in fusion, increase the heat for an hour, or an hour and a half. When the crucible has cooled, break it, and detach its contents ; reduce them to powder, and boil them with distilled water. Let the insoluble part subside ; decant the clear liquor, and wash the sediment with water, till the washings cease to precipitate muriated barytes. On the residuum pour muriatic acid to excess, and boil it during a quarter of an hour ; filter the liquor, and evaporate to dryness in a leaden vessel. Re-dissolve the dry mass ; filter again, and precipitate the zircon with carbonate of soda. The carbonate of zircon is thus obtained, from which the carbonic acid may be expelled by calcination.

II. Zircon has the following properties :

1. It has the form of a fine white powder, which has somewhat the harsh feel of silex, when rubbed between the fingers. It is entirely destitute of tatse and smell.

2. It is insoluble in water ; yet is appears to have some affinity for that fluid, for it retains, when slowly dried after precipitation

one-third its weight, and assumes a yellow colour and slight transparency, like that of gum Arabic.

3. It is insoluble in pure liquid alkalis; nor does it even combine with them by fusion; but it is soluble in alkaline carbonates. In the foregoing process, therefore, the carbonate of soda should not be added to excess.

4. Exposed to a strong heat, zircon fuses, assumes a light grey colour; and such hardness, on cooling, as to strike fire with steel, and to scratch glass.

5. Its action on other earths has not been fully investigated.

6. It is precipitated from its solutions in acids by triple prussiate of potash. (Klaproth, ii. 214.)

SECTION VIII.

Glucine.

I. This earth was discovered by Vauquelin, in the year 1798. He obtained it from the aqua marine or beryl, a precious stone of a green colour, and very considerable hardness, which is found crystallized in Siberia. Glucine has since been detected in the emerald of Peru, and in the gadolinite. The following process may be employed to separate it from the beryl:

Let the stone, reduced to a fine powder, be fused with three times its weight of pure potash. To the fused mass add a quantity of water, and afterwards diluted muriatic acid; which last will effect a complete solution. Evaporate the solution to dryness, re-dissolve the dry mass, and add carbonate of potash so long as any precipitation ensues. Dissolve the precipitate in sulphuric acid, add the sulphate of potash; and, on evaporation, crystals of alum will be obtained. By this process the alumine is detached. The residuary liquor, which yields no more crystals, contains the glucine, and a small portion of alumine. Add a solution of carbonate of ammonia to excess; this will throw down the alumine, and the glucine will remain dissolved by the superabundant carbonate. When this solution is evaporated to dryness, and moderately heated, the alkaline carbonate is expelled, and a carbonate of glucine remains, in the proportion of 16 parts from every 100 parts of the stone.

II. Glucine has the following properties:

1. It is a fine white and soft powder, resembling alumine in its sensible properties; and, like that earth, adhering to the tongue.

2. It has no action on blue vegetable colours.

3. It does not harden, or contract, like alumine, by heat; and is infusible.

4. It is insoluble in water, but forms with it a ductile paste.

5. It is soluble in liquid potash and soda, but not in the solution of pure ammonia. In these respects it agrees with alumine.

6. Glucine is soluble in carbonate of ammonia; a property distinguishing it from alumine.

7. It appears, like alumine, to have an affinity for colouring matter.

8. With the different acids it forms combinations, which have a sweet and rather astringent taste. Hence its name has been derived from γλυκυς, signifying sweet.

9. It is not precipitated by triple prussiate of potash.

SECTION IX.

Yttria, or Ittria.

I. This earth was discovered in 1794, by Professor Gadolin, in a stone from Ytterby in Sweden, and its title to the character of a peculiar earth rests, also, on the unquestionable authority of Klaproth and Vauquelin, both of whom have made it the subject of experiment. The following process for obtaining it, is described by Vauquelin in the 36th volume of the Annales de Chimie, p. 150.

Fuse the pulverized stone (called Gadolinite), in the manner already described, with twice its weight of potash; wash the mass with boiling distilled water, and filter. The filtered solution, which has a beautiful green colour, yields, during evaporation, a black precipitate of oxide of manganese. When this has ceased to appear, allow the liquor to stand; decant the clear part, and saturate with nitric acid. Let the insoluble part be, also, digested with extremely dilute nitric acid, which will take up the soluble earths only, and will leave, undissolved, the silex and oxide of iron. Let the two portions be mingled together, and evaporated to dryness; then re-dissolved and filtered: by which means any remains of silex and oxide of iron are separated. To obtain the yttria from the nitric solution, it would be sufficient, if no other earth were present, to precipitate it by carbonate of ammonia; but small portions of lime, and of oxide of manganese, are still present along with it. The first is separated by a few drops of carbonate of potash; and the manganese, by the cautious addition of hydro-sulphuret of potash. The yttria is then to be precipitated by pure ammonia, washed abundantly with water, and dried. It amounts to about 35 *per cent.* of the stone.

II. Yttria has the following properties:

1. It is perfectly white; but it is difficult to preserve it free from a slight tinge of colour, owing to its contamination with oxide of manganese.

2. It has neither taste nor smell; and it is smooth to the touch, like alumine.

3. It is insoluble in water, and infusible by heat.

4. It is very ponderous; its specific gravity being 4.842.

5. It is not attacked by pure alkalis; and, in this respect, it differs from glucine and alumine, both which are abundantly soluble in fixed alkalis.

6. Like glucine, it is soluble in carbonate of ammonia, but five or six times less so than that earth; or, in other words, of equal quantities of glucine and yttria, the latter requires for solution five or six times more of the carbone of ammonia than the former.

7. It is soluble in most acids; and is precipitated by pure alkalis, by barytes, and by lime.

8. From these solutions it is also precipitated by the oxalic acid, and by oxalate of ammonia, in a state resembling precipitated muriate of silver. Prussiate of potash throws it down in white small grains passing in a short time to pearl grey; phosphate of soda in a white gelatinous form; and infusion of galls in brown flocculi.

9. Yttria, which has been a long time exposed to the action of fire, gives out oxygenized muriatic acid, when dissolved in common muriatic acid; thus manifesting one property of a metallic oxide. (Nich. Journ. xviii. 77.)

CHAPTER IX.

ACIDS IN GENERAL.

Acids in general have the following properties:

(*a.*) *They redden vegetable blue colours.* [See Note 14.] 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 alkalis, earths, and oxides, 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 alkali nor the acid is in excess ; or, in other words, they are exactly *saturated* by each other. One of the most remarkable properties of the alkali 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.

CHAPTER X.

CARBON.—CARBONIC ACID.—CARBONATES.—BINARY COMPOUNDS OF CARBON.

SECTION I.

Carbon and Charcoal. [See Note 15.]

I. It has been, hitherto, generally admitted as an established truth, chiefly on the evidence of the experiments of Guyton (Annales de Chim. xxxi.), that the diamond is the only form of pure carbon ; and that charcoal is a compound of carbon and oxygen, or an oxide of carbon. The recent and very important experiments of Messrs. Allen and Pepys have proved, however, that the diamond and charcoal, though so widely remote from each other in external characters, are, as to their chemical nature, identically the same ; and that the difference between them, in all probability, results merely from the respective states of aggregation of their particles.

To obtain charcoal free from contamination, pieces of oak, willow, hazle, or other woods, deprived of the bark, must be buried in sand in a crucible, which is to be exposed, covered, to the strongest heat of a wind-furnace.

For purposes of accuracy, charcoal must be used when recently prepared, and before it has had time to become cold ; or if it cannot be had fresh made, it must be heated again to redness under sand in a crucible.

From 100 parts of each of the following woods, Messrs. Allen and Pepys obtained the annexed quantities of charcoal; viz. from fir, 18.17; lignum vitæ, 17.25; box, 20.25; beech, 15; oak, 17.40; mahogany, 15.75.

II. Charcoal has the following properties:

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

2. Charcoal has the singular property of absorbing gases, 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.

Count Morozzo has given the following Table of the quantities of different gases absorbed, in the foregoing manner, by charcoal. In each experiment, he employed a piece of that substance 1 inch long and $\frac{3}{4}$ of an inch diameter. The receiver containing gas was 12 inches long and 1 inch diameter.

Gas absorbed.	*Inches.*	*Gas absorbed.*	*Inches.*
Atmospheric	$3\frac{1}{2}$	Nitrous	$6\frac{5}{6}$
Carbonic acid	11	Hydrogen	$2\frac{1}{12}$
Ammonia	11	Oxygen	$2\frac{1}{6}$
Muriatic acid	11	Sulphurous acid	$5\frac{1}{2}$
Sulphuretted hydrog.	11		

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

4. Charcoal, by long exposure to the atmosphere, absorbs one-twentieth of its weight, three-fourths of which are water. (Clement and Desonnes.)

The charcoal of different woods, Messrs. Allen and Pepys found to increase very differently in weight; that from fir gaining, by a week's exposure, 13 per cent.; that from lignum vitæ, in the same time, 9.6; from box, 14; beech, 16.3; oak, 16.5; mahogany, 18. The absorption goes on most rapidly during the first 24 hours; and by much the largest part of what is absorbed consists of water merely.

5. Charcoal resists the putrefaction of animal substances. A piece of flesh-meat, which has begun to be tainted, may have its sweet-

ness restored by rubbing it daily with powdered charcoal; and may be preserved sweet for some time by burying it in powdered charcoal, which is to be renewed daily. Putrid water is also restored by the application of the same substance; and water may be kept unchanged at sea, by charring the inner surface of the casks which are used to contain it. (Lovitz An. de Ch. xiv.)

6. Charcoal is a very slow conductor of caloric. The experiments of Guyton have determined, that caloric is conveyed through charcoal more slowly than through sand, in the proportion of three to two. Hence powdered charcoal may be advantageously employed to surround substances which are to be kept cool in a warm atmosphere; and also to confine the caloric of heated bodies.

SECTION II.

Combustion of Carbon.

If a small piece of charcoal be exposed red-hot to the common atmospheric air, it exhibits scarcely any signs of combustion, and soon becomes cold. But if a similar piece, heated to redness, be introduced into a receiver filled with oxygen gas, it continues to burn with greatly increased splendour, and with bright scintillation. The diamond, if intensely heated, by the focus of a burning lens or otherwise, may also be consumed in oxygen gas; but its combustion is much slower and less vivid than that of charcoal.

To collect the products of the combustion of carbon, requires rather a complicated apparatus. Lavoisier burnt charcoal in a known quantity of oxygen gas, which was confined by mercury, setting fire to the charcoal by a bent iron wire heated to redness. (Elements of Chemistry, pl. iv. fig. 3.) Messrs. Allen and Pepys collected the products of the combustion of charcoal and of the diamond, by burning them separately in a platina tube, set horizontally in a charcoal furnace, and connected, at each extremity, with a mercurial gazometer. An idea of this arrangement will best be obtained by imagining that to each end of the tube *c*, fig. 40. the pipe *b* of a gazometer, like that shown, fig. 35. is connected. At the outset of the experiment, one of the gazometers was filled with a known quantity of the purest oxygen gas, and the other was empty. The tube was then made red-hot; and the gas, being forced alternately from one gazometer to the other, was repeatedly brought into contact with the red-hot charcoal or diamond. The volume of the gas was found to be entirely unaltered; but it had received an addition to its weight, precisely equal to what the charcoal or diamond, on weighing, was ascertained to have lost; and it was partly converted into a gas, totally different in its properties from oxygen gas, and called carbonic acid.

SECTION III.

Carbonic Acid.

I. From the quantity of charcoal or diamond consumed, and the quantity of oxygen converted into carbonic acid, it was easy to infer the proportion of carbon and oxygen in the new compound. Reducing these to centesimal proportion, for every 28 or 29 grains of the combustible base which had disappeared, 100 grains of carbonic acid (=about 201 cubic inches) were generated; and it is remarkable that these proportions agree exactly with those originally stated by Lavoisier. The same quantity of carbonic acid resulted, also, from the combustion of between 28 and 29 grains of diamond. Hence it may be inferred, that the actual quantity of carbon in equal weights of diamond and charcoal is precisely the same; and that charcoal is not, as has hitherto been supposed, an oxide of carbon. If this inference required confirmation, it is furnished by its agreement with Mr. Tennant's experiments on the combustion of the diamond, published in 1797. The mean of a number of experiments gave the following statement of the composition of carbonic acid:

$$\left.\begin{array}{r}\text{100 parts by weight}\\ \text{consist of} \;\ldots\ldots\end{array}\right\}\begin{array}{l}\text{28.60 carbon}\\ \text{71.40 oxygen.}\\ \hline \text{100}\end{array}$$

II. To procure carbonic acid, sufficiently pure for the exhibition of its properties, the combustion of charcoal is far from being the best process. 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 five or six 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.

A person, says Dr. Priestley, who is quite a stranger to the properties of this kind of gas, will be agreeably amused with extinguishing lighted candles, or blazing chips of wood, on its surface. For the smoke readily unites with this kind of air; so that little or none of it escapes into the atmosphere. It is remarkable, that the upper surface of this smoke, floating in the fixed air, is smooth and well defined; whereas the lower surface is exceedingly ragged, several parts hanging down to a considerable distance within the body of the carbonic acid, and sometimes in the form of balls, connected to the upper stratum by slender threads, as if they were suspended. The smoke is also apt to form itself into broad flakes, exactly like clouds. Making an agitation in this air, the surface of it (which still continues exactly defined) is thrown into the form of waves; and if, by this agitation, any of the carbonic acid be thrown over the sides of the vessel, the smoke, which is mixed with it, will fall to the ground, as if it was so much water.

(*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.

By means of this gas, butterflies, and other insects, the colours of which it is desirable to preserve, for the purpose of cabinet specimens, may be suffocated better than by the common mode of killing them with the fumes of sulphur.

(*c.*) *This gas is heavier than common air.*—According to Mr. Davy, 100 cubic inches, at 55° Fah^{t} and 30 inches of the barometer, weigh 47.5 grains; and at 60° with the same pressure, would weigh 47.11. Messrs Allen and Pepys have lately determined that 100 cubic inches, at 60° Fah^{t} and 30 inches barometer, weigh 47.26 grains.

To show the superior specific gravity of this gas in a general way, the following experiment, will be sufficient. Let a long glass-tube, proceeding from a gas-bottle containing the materials (No. 1.), be twice bent at right angles: 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 further 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 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 rather more than 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 by 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 by 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 is expelled from water by freezing.*—If the impregnated water be rapidly congealed, by surrounding it with a mixture of snow and salt, the frozen water has more the appearance of snow than of ice, its bulk being prodigiously increased by the immense number of air bubbles. When water, thus congealed, is liquefied again, it is found, by its taste, and other properties, to have lost nearly the whole of its carbonic acid.

(*g.*) *Carbonic acid gas, when combined with water, reddens vegetable blue colours.*—This may be shown by dipping into water, thus separated, 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.

(*h.*) *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. By means of lime-water, the whole of any quantity of carbonic acid existing in a mixture of gases, may be entirely removed.

(*i.*) *By the application of the test (h), it will be found, that carbonic acid is generated in several cases of combustion.*—1. Let the chimney of a small portable furnace, in which charcoal is burning, terminate, at a distance sufficiently remote to allow of its being kept cool, in the bottom of a barrel provided with a moveable top, or of a large glass vessel having two openings. A small jar of lime-water being let down into the tub or vessel, and agitated, the lime-water will immediately become milky. The gas will also extinguish burning bodies, and prove fatal to animals that are confined in it. Hence the danger of exposure to the fumes of charcoal, which, in several instances, have been known to be fatal. These fumes consist of a mixture of azotic and carbonic acid gases with a very small proportion of oxygen gas. 2. 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 oxygen gas be substituted for common air. 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 oxygen 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. Whenever any substance, by combustion in oxygen gas or common air over lime-water, gives a precipitate, soluble with effervescence in muriatic acid, we may confidently infer that it contains carbon.

(*k.*) *The respiration of animals is another source of carbonic acid.* [See additions at the end.]—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 oxygen 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 it is 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 contains a larger proportion of oxygen than the air we commonly breathe.

(*l.*) *Carbonic acid retards the putrefaction of animal substances.*—This may be proved, by suspending two equal pieces of flesh-meat, the one in common air, the other in carbonic acid gas, or in a vessel through which a stream of carbonic acid is constantly passing. The latter will be preserved untainted some time after the other has begun to putrefy.

(*m.*) *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 the undiluted gas over water, 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 the growth of plants, and is manifestly decomposed.

III. 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.

SECTION IV.

Carbonates.

Art. I.—*Carbonate of Potash.*

(*a.*) *Carbonic acid gas is very abundantly absorbed by a solution of pure potash.*—The simplest mode of showing this fact is the following: Fill a common phial with carbonic acid 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 exceeding in quantity what 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 alkaline 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.

This experiment may be made, in a much more striking manner, over mercury, by passing into a jar, about three-fourths filled with this gas, a comparatively small bulk of a solution of pure potash, which will condense the whole of the gas. If dry potash be substituted in this experiment, no change will ensue; which proves, that solution is essential to the action of alkalis on this gas.

(*b.*) *The changes effected in the alkali may next be examined.*—It will be found, after having absorbed as much carbonic acid as it is capable of condensing, to have lost much of its corrosive and penetrating taste, and will no longer destroy the texture of woollen cloth; but it still turns to 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 almost 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 sub-saturation 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 *sub-carbonates* of potash, of different degrees of purity. The quantity of carbonic acid, contained in these alkalis, may be learned by a very simple experiment. Put one or two hundred grains of the alkali 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 alkali, till an effervescence no longer ensues. When this has ceased, the scale containing the weights will be found to preponderate. This shows that the alkali, 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 alkali 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 alkali is in proportion to the quantity of any 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 alkali will be learned, by observing what quantity of this acid a given quantity of alkali requires for saturation. For this purpose, put half an ounce of the alkali, or any other definite weight, into a jar with a few ounces of water, and filter the solution; weigh the dilute acid employed, before adding it to the alkali; 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 alkali. Another less accurate mode of determining the strength is founded on the following property of carbonate of potash.

(*e.*) *Sub-carbonate of potash dissolves very readily in water, which, at the ordinary temperature, takes up more than its own weight.*—Hence, when an alkali, which should consist almost entirely of sub-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.*) Sub-carbonate of potash, when exposed to the atmosphere, attracts so much moisture, as to pass to a liquid state. This change is termed *deliquescence.*

(*g*). When submitted, in a crucible, to a high temperature, a part only of its carbonic acid is expelled. The alkali runs into fusion, and the fused mass still effervesces on the addition of an acid.

(*h.*) 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 alkaline 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; or by the process to be described in Art. iii. *g*. When a solution of alkali, after this treatment, is slowly evaporated, it forms regular crystals. In this state the alkali constitutes the crystallized carbonate of potash, which contains per cent. 40 parts of potash, 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 alkali, 23 of acid, and 5 of water.

(*i.*) The CARBONATE OF POTASH differs from the sub-carbonate in the following particulars.

1. In the greater mildness of its taste. It may be applied to the tongue, or taken into the stomach, without exciting any of that burning sensation, which is occasioned by the sub-carbonate.

2. It is unchanged by exposure to the atmosphere.

3. It assumes the shape of regular crystals. The form of these crystals is a four-sided prism, with dihedral triangular summits, the facets of which correspond with the solid angles of the prism.

4. It requires, for solution, four times its weight of water at 60°. Boiling water dissolves 5-6ths of its weight; but, during this solution, the salt is partly decomposed, as is manifested by the escape of carbonic acid gas.

5. By calcination in a low red-heat, the portion of carbonic acid, which imparts to this salt its characteristic properties, is expelled, and the salt returns to the state of a sub-carbonate.

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

This may be shown by pouring, on the carbonate contained in a gas bottle, any of the acids, and collecting the gas by a proper apparatus.

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

ART. II.—*Carbonate of Soda*. [See Note 16.]

The combination of carbonic acid with soda, like that of the same acid with potash, exists in two very different states, viz. in those of a *sub-carbonate*, and of perfectly saturated *carbonate*.

1. The substance, generally met with in the shops, under the name of soda, affords an example of the *sub-carbonate*. This salt 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. They have the form of decahedrons, which are composed of two four-sided pyramids, applied base to base, and have their apices truncated. They frequently, also, present large transparent flat rhomboidal prisms. Water, of the temperature of 60°, takes up half its weight; and boiling water rather more than its own weight. In 100 parts, this salt contains, according to Bergman, 16 carbonic acid, 20 soda, and 64 water.

The *carbonate of soda* may be found either by the process described in the foregoing article *h*, or by that which will be given in the following article, *g*. It is with considerable difficulty brought to crystallize, and affords generally a shapeless mass. Its taste is considerably milder than that of the sub-carbonate of soda, and even than that of neutral carbonate of potash. In 100 parts, it contains, according to Klaproth, 39 acid, 38 soda, 23 water.

ART. III.—*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 aerial fluid. But, when these two gases are mixed together over mercury in proper proportions (viz. one measure of carbonic acid to two or three of alkaline gas), they both quit the state of gas, and are entirely condensed into a white solid body, termed carbonate of ammonia.

Those persons who are not possessed of a mercurial trough, may compose the carbonate of ammonia, in the following manner:—Provide a globular receiver, having two open necks opposite each other. Into one of these introduce the neck of a retort, containing carbonate of lime and dilute sulphuric acid, from which a constant stream of carbonic acid will issue. The inner surface of the globe will remain perfectly unclouded. Into the opposite opening, let the mouth of a retort be introduced, containing the materials for ammoniacal gas. (Chap. vii. sect. 2.) The inner surface of the globe will now be covered with a dense crust of carbonate of ammonia.

The carbonate of ammonia may also be formed, by passing, into a jar 3-4ths filled with carbonic acid over mercury, a solution of pure ammonia, which will instantly effect an absorption of the gas. The ordinary mode of producing it for useful purposes will be described hereafter.

(*b.*) Carbonate of ammonia retains, in a considerable degree, the pungent smell of the pure volatile alkali. 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.

(*d.*) Carbonate of ammonia, like those of potash and soda, converts vegetable blue colours to green, as the pure alkalis do.

(*e.*) It is soluble in rather less than twice its weight of cold water, or in an equal weight of boiling water. At the latter temperature, however, it is partly decomposed, and a violent effervescence ensues.

(*f.*) In composition it varies considerably, according to the temperature in which it has been formed. Thus, carbonate of ammonia, which has been produced in a temperature of 300° Fahrenheit, contains 50 per cent. of alkali; while carbonate formed at 60° contains only twenty per cent.

(*g*.) It is decomposed by pure potash and pure soda; and by the sub-carbonates of those alkalis, which attract its carbonic acid, and expel the alkali. Hence it has been recommended, by Berthollet, to employ this salt for the full saturation of potash with carbonic acid, which may be accomplished by the following process.

To a filtered solution of four pounds of pearlash in four quarts of water, add two pounds of carbonate of ammonia, reduced to powder; and stir the mixture at intervals, till the carbonate of ammonia is entirely dissolved. Filter the liquor, and put it into a retort, which may be set in a sand-bath, and be connected with a receiver. A very gentle heat is to be applied; so as to distil off about half a pint of the liquor, which will consist of a solution of carbonate of ammonia in water. The liquor in the retort may either be allowed to cool in it, or be transferred into a flat evaporating dish of Wedgewood's ware. When cold, crystals of the carbonate of potash will probably be formed; otherwise another portion must be distilled off, and this must be repeated till the crystals appear; separate the first crystals that are formed; and, on repeating the distillation and cooling, fresh sets will appear in succession. A considerable portion of the solution, however, will refuse to crystallize. This may be boiled to dryness, and applied to the purposes of sub-carbonate of potash. The crystals of carbonate of potash may be washed with a small quantity of cold water, and dried on blotting paper; or, if they are required of great purity, they may be dissolved in cold water, and recrystallized, using the gentlest heat possible in evaporating the solution.

ART. IV.—*Carbonate of Barytes.*

I. Pure barytes has a very powerful affinity for carbonic acid.

1. Let a solution of pure barytes be exposed to the atmosphere. It will soon be covered with a thin white pellicle; which, when broken, will fall to the bottom of the vessel, and be succeeded by another. This may be continued, till the whole of the barytes is separated. The effect arises from the absorption of carbonic acid, which is always diffused through the atmosphere, and which forms with barytes a substance, viz. carbonate of barytes, much less soluble than the pure earth.

2. Blow the air from the lungs, by means of a quill, a tobacco pipe, or glass tube, through a solution of barytes. The so-

lution will immediately become milky, for the same reason as before.

3. With a solution of pure barytes, mingle a little water, impregnated with carbonic acid. An immediate precipitation of carbonate of barytes will ensue.

4. Barytes has so strong an affinity for carbonic acid, as even to take it from other bodies. To a solution of a small portion of carbonate of potash, of soda, or of ammonia, add the solution of barytes. The barytes will separate the carbonic acid from the alkali, and will fall down in the state of a carbonate. By adding a sufficient quantity of a solution of barytes in hot water, the whole of the carbonic acid may thus be taken from a carbonated alkali; and the alkali will remain perfectly pure.

II.—1. Carbonate of barytes is nearly insoluble in water, which, at 60°, does not take up more than $\frac{1}{4300}$ part, or, when boiling, about $\frac{1}{2300}$. Water impregnated with carbonic acid dissolves a considerably larger proportion.

2. Carbonate of barytes is perfectly tasteless, and does not alter vegetable blue colours. It acts as a violent poison.

3. The combination of carbonic acid with barytes may either be formed artificially, as in the manner already described, and by other processes, to be detailed in the sequel, in which case it is termed, the *artificial carbonate:* or it may be procured, ready formed, from the earth, and is then called the *native carbonate.* It is not, however. a very common production of nature. The largest quantity, hitherto discovered, is in a mine, now no longer worked, at Anglezark, near Chorley, in Lancashire.

4. The native and artificial carbonates differ in the proportion of their components. The former contains, in 100 parts, 20 acid and 80 barytes. The artificial, according to Pelletier, consists of 22 acid, 62 earth, and 16 water.

5. Carbonate of barytes is decomposed by an intense heat; its carbonic acid being expelled; and the barytes remaining pure. The artificial carbonate is most readily decomposed; but the native one is generally employed for obtaining pure barytes, because it may be had in considerable quantity. The process, which I have found to answer best, is nearly that of Pelletier. Let the native carbonate be powdered, and passed through a fine seive. Work it up with about an equal bulk of wheaten flour into a ball, adding a sufficient quantity of water. Fill a crucible of proper size, about one-third its height, with powdered charcoal; place the ball on this; and surround and cover it with the

same powder, so as to prevent its coming into contact with the sides of the crucible. Lute on a cover; and expose it, for two hours, to the most violent heat that can be raised in a wind furnace. Let the ball be removed when cold. On the addition of water, it will evolve great heat, as already described (ch. viii.), and the barytes will be dissolved. The filtered solution, on cooling, will shoot into beautiful crystals.

6. Carbonate of barytes is decomposed by the sulphuric, nitric, muriatic, and various other acids, which detach the carbonic acid, and combine with the earth.

ART. V.—*Carbonate of Strontites.*

The relation of strontites to carbonic acid resembles, very closely, that of barytes; and all the experiments, directed to be made with the solution of the latter earth, may be repeated with that of strontites, which will exhibit similar appearances.

The carbonate of strontites requires for solution 1536 parts of boiling water. It is found native at Strontian in Argyleshire; and may, also, be prepared by artificial processes, which will be afterwards described. From this carbonate pure strontites may be prepared, by treating it in the same manner as was directed for the calcination of carbonate of barytes.

ART. VI.—*Carbonate of Lime.*

1. 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 the bottle be agitated.

(*b.*) Let a jar or bottle, filled with carbonic acid, be brought over a vessel of lime-water. On agitating the vessel, a rapid 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 alkalis are decomposed by lime. Slake a given quantity of lime into a paste with water, and add half its weight of carbonate of potash or soda. Boil the mixture, for half an hour, in an iron kettle, and separate the liquid part by filtration or by subsidence. The carbonic acid combines with the lime, and the alkali is obtained in a state of solution perfectly free from carbonic acid. This is the ordinary mode of depriving the alkalis 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. Calcareous spar, marble, stalacites, lime-stone, and chalk, are all varieties of carbonate of lime.

(*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. By this process it loses about 50 per cent.

The very curious and important experiments of Sir James Hall have proved, that when the escape of the carbonic acid is prevented by strong pressure, carbonate of lime is fusible in a heat of about 22° of Wedgewood's pyrometer. (Nich. Journ. xiii. xiv.) And Mr. Buchòlz has lately fused this substance, by the sudden application of a violent heat, without additional compression. (Nich. xvii. 229.)

(*h.*) Carbonate of lime is 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.

By a comparison of this experiment with the preceding one (*g*), we may learn the proportion of carbonic acid and water contained in any carbonate of lime. Let 100 grains of the carbonate be put into a Florence flask, with an ounce or two of water; place this in the scale of a balance; and in the same scale, but in a separate bottle, about half an ounce of muriatic acid. Add the muriatic acid to the carbonate as long as any effervescence is produced, and then blow out the disengaged carbonic acid, which remains in the flask, by a pair of bellows. Ascertain, by adding weights to the opposite scale, how much has been lost; suppose it to be thirty-five grains; this shows the quantity of carbonic acid disengaged. Calcine another 100 grains in a covered crucible. It will lose still more of its weight; because, besides its carbonic acid, all the water is expelled which it may contain. Let this loss be stated at 50 grains; the former loss deducted from this (50—35), or 15 grains, shows the quantity of water in 100 of the carbonate.

(*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 re-dissolved. Hence it appears that lime, with a certain 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 (*i*), is again separated, when this excess is driven off. Thus boiling, which expels the superabundant acid, precipitates the carbonate. Caustic, or pure alkalis, also produce a similar effect.

ART. VII.—*Carbonate of Magnesia.*

I. Pure magnesia does not attract carbonic acid with nearly the same intensity as lime. Hence magnesia may be exposed, for a long time, to the air, without any important change in its properties, or much increase of weight. The carbonate of magnesia, used in medicine, and for experimental purposes, is prepared by a process to be described in the sequel. In this state, however, it is not entirely saturated with carbonic acid, and is rather a sub-carbonate.

II. The saturated carbonate may be obtained, by passing streams of carbonic acid gas through water, in which the subcarbonate is kept mechanically suspended. The solution yields, when evaporated, small crystals, which are transparent hexagonal prisms, terminated by hexagonal planes. These crystals have no taste, and are soluble in 48 parts of cold water; whereas the sub-carbonate requires at least ten times that quantity. The crystallized carbonate contains per cent. 50 acid, 25 earth, and 25 water; the sub-carbonate 34 acid, 45 earth, and 21 water.

III. The carbonate of magnesia is decomposed by the same agents as the carbonate of lime. It yields its carbonic acid, however, in a much more moderate heat.

IV. Lime has a stronger affinity than magnesia for carbonic acid. Hence, if lime-water be digested with carbonate of magnesia, the lime is precipitated in the state of an insoluble carbonate.

ART. VIII.—*Carbonate of Glucine.*

I. Glucine appears to have a considerable affinity for carbonic acid; for, when precipitated from acids by pure alkalis, and dried in the air, it becomes effervescent. The carbonate of glucine is white, insipid, insoluble, and very light. It contains about one-fourth its weight of carbonic acid, which it loses by exposure to a low red-heat.

The carbonate of silex does not exist, and those of zircon, alumine, and yttria, have no peculiarly interesting properties.

SECTION V.

Gaseous Oxide of Carbon, or Carbonic Oxide.

This combination of carbon with oxygen contains a less proportion of oxygen 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 acknowledgement of the gaseous oxide as a new and peculiar species.

I. It may be procured by any of the following processes:

1. By the distillation of the white oxide of zinc with 1-8th its weight of charcoal, in an earthen or glass retort; from the scales which fly from iron in forging, mixed with a similar proportion of charcoal; from the oxides 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 acetate of copper.

2. From well dried carbonate of barytes or of lime (common chalk), distilled with about 1-5th of charcoal; or with rather a

larger proportion of dry iron or zinc filings, which afford it quite free from hydrogen.

3. By transmitting carbonic acid gas over charcoal ignited in a porcelain tube. The acid gas combines with an additional dose of charcoal; loses its acid properties; and is converted into the carbonic oxide. An ingenious apparatus, contrived by M. Baruel, and extremely useful for this and similar purposes, is described, and represented by a plate, in the 11th volume of Nicholson's Journal.

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

II. Its properties are as follow:

(*a*.) It has an offensive smell.

(*b*.) It is lighter than common air, in the proportion of 966 to 1000. One hundred cubical inches weigh 30 grains, the temperature being 55° Fah^{t}, and pressure 29.5, (Cruickshank); or at temperature 60°, and barometer 30, 100 cubic inches weigh 30.19 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 gases, 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, no water is condensed on the inner surface of the glass globe, a proof that the gaseous oxide contains no hydrogen.

(*e*.) It is sparingly soluble in water; is not absorbed by liquid caustic alkalis; nor does it precipitate lime-water.

(*f*.) It is extremely noxious to animals; and fatal to them if confined in it. When respired for a few minutes, it produces giddiness and fainting.

(*g*.) When 100 measures of carbonic oxide are fired over mercury in a detonating tube, with 45 of oxygen gas, the total 145 are diminished to 90, which consist entirely of carbonic acid.

(*h*.) It is not expanded by electric shocks.

(*i*.) When the carbonic oxide, mingled with an equal bulk of hydrogen gas, is passed through an ignited tube, the tube becomes lined with charcoal. In this temperature, the hydrogen attracts oxygen more strongly than it is retained by the charcoal, and forms water.

According to Mr. Cruickshank, it contains per cent. about 70 oxygen, and 30 carbon by weight ; or the former is to the latter as 21 to 8.6, or as 21 to 9.

SECTION VI.

Combination of Carbon with Hydrogen, forming Carburetted Hydrogen Gas, or Hydro-Carburet.

I. Of this combination there appear, on first view, to be several distinct varieties, consisting of carbon and hydrogen, united in various proportions, and obtained by different processes.

1. When the vapour of water is brought into contact with red-hot charcoal (by means of an apparatus similar to that represented, fig. 40.) two different products are obtained. The oxygen of the water, uniting with the carbon, constitutes carbonic acid ; and the hydrogen of the water dissolving, at the moment of its liberation, a portion of charcoal composes carburetted hydrogen gas*. The carbonic acid may be separated from the hydro-carburet, by agitating the gas, which has been produced, in contact with lime and water, mixed together, so as to be of the consistence of cream.

2. By stirring, with a stick, the mud that is deposited at the bottom of ditches or stagnant pools, bubbles of gas ascend to the surface, and may be collected in an inverted bottle of water, to the mouth of which a funnel, also inverted, is fixed.

3. By submitting coal [see Note 17.] to distillation, in an iron or coated glass retort, a large quantity of gas, besides a portion of tar, is produced. The latter may be received in an intermediate vessel ; and the gas must be well washed with lime-liquor.

4. Let a porcelain tube, coated with clay, be fixed horizontally in a furnace, in the manner represented, fig. 40. To one end let a retort be luted, containing an ounce or two of ether or alcohol ; and, to the other, a bent tube, which terminates under the shelf of the pneumatic trough. A gas will be disengaged, on igniting the tube, and transmitting, through it, the alcohol or ether in vapour, which, when washed with lime-liquor, is the carburetted hydrogen.

5. A fifth mode of obtaining hydro-carburet, consists in distilling, in a glass retort, with a gentle heat, three parts of concentrated sulphuric acid, and one part of alcohol. The mixture assumes a black colour and thick consistence ; and bubbles of

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* In Nicholson's Journal, xi. 68 I have stated my reasons for believing that this gas is not pure hydro-carburet.

gas are disengaged, which may be collected over water. For reasons which will afterwards be stated, this gas has been named the olefiant gas.

II. These varieties of carburetted hydrogen gas all agree in being inflammable ; but they possess this property in various degrees, as is evinced by the variable brightness of the flame, which they yield when set on fire. They may be inflamed as they proceed from the orifice of a small pipe, or from between two concentric cylinders of sheet-iron or copper, placed at the distance of a small fraction of an inch from each other. On this principle, an Argand's lamp may be constructed, for burning the gases, which will issue from that space, commonly occupied by the wick.

1. When burned in either of these modes, there is a manifest gradation in the density and brightness of the flame. The gas from charcoal burns with a faint blue light, not suited to the purpose of illumination ; that from ether or alcohol with more brilliancy ; but still short of that with which the coal gas burns, when recently prepared. The olefiant gas surpasses them all, in the quantity of light evolved by its combustion.

2. If these gases be burned in a vessel of oxygen gas over lime-water, by means of a bladder and bent brass pipe (plate iv. fig. 41.), two distinct products are obtained, viz. water and carbonic acid. That water is produced, may be shown by burning a very small stream of this gas under a long funnel-shaped tube open at both ends. The formation of carbonic acid is evinced, by the copious precipitation of the lime-water in the foregoing experiment.

3. The composition of each of the above gases is learned by firing it, in a detonating tube over mercury, with a known quantity of oxygen gas ; and observing the nature and quantity of the products. These products are carbonic acid and water. The former may be exactly measured ; but the water is generated in such small quantity, that it can only be computed. The following table shows the results of a few experiments of this kind.

Kind of Gas.	Measures of Oxygen Gas required to saturate 100 Measures.	Measures of Carbonic Acid produced.
Pure hydrogen gas	50 to 54	
Gas from charcoal	60	35
——— coal	170	100
——— stagnant water	200	100
Olefiant gas	284	179

Now since, for the formation of each measure of carbonic acid gas, in the foregoing experiments, an equal volume of oxygen gas is required, we may learn, by deducting the number in the third column from the corresponding one in the second, what proportion of oxygen has been allotted to the saturation of the hydrogen of each hydro-carburet. Thus, for example, in burning the gas from coal, 100 measures of oxygen have been employed in forming carbonic acid; and the remaining 70 in saturating hydrogen. But 70 measures of oxygen are sufficient to saturate 140 of hydrogen gas; and a quantity of hydrogen must therefore be contained in 100 measures of gas from coal; which, expanded to its usual elasticity, would occupy 140 measures.

4. The gases vary in their solubility by water, the olefiant gas being absorbed in the largest proportion, viz. 1-8th the bulk of the water; the gas from stagnant water 1-64th; and the others in still less quantity.

5. They vary also in density or specific gravity. Common air being 1000, the olefiant gas is 909; the gas from ether or alcohol 520; and from moistened charcoal 480. The specific gravity of gas from coal, and of that from stagnant water, I am informed by Mr. Dalton, are the same, viz. 666, or as 2 to 3.

6. The only distinct and well characterized species of hydro-carburet appear to me to be the olefiant gas; and the gas from stagnant water, yielding by combustion, an equal bulk of carbonic acid. Of these, the other varieties appear to be only mixtures. The reasons for this opinion I have stated in Nicholson's Journal, vol. xi. p. 68.

CHAPTER XI.

SULPHUR.—SULPHURIC ACID.—SULPHATES.—BINARY COMPOUNDS OF SULPHUR.

SECTION I.

Sulphur. [See additions at the end.]

I. SULPHUR occurs in two different forms; that of flowers, and of stick or roll sulphur. The former is considerably the purest.

II. Sulphur is readily fused and volatilized. When heated to 170° of Fahrenheit, it begins to evaporate, and to produce a very disagreeable smell; at 185° or 190° it begins to melt; and at 220° is completely fluid. If the heat be rapidly increased, it loses its fluidity, and becomes firm, and of a deeper colour. It regains its fluidity, if we reduce the temperature; and this may be repeated at pleasure, in close glass vessels, if the changes of heat be not slow; otherwise it begins to evaporate.

III. If, after being melted, it be suffered to cool, it congeals in a crystalline form, [See Note 18.] but so confusedly, that we cannot define the shape of the crystals, further than that they are slender interlaced fibres. If a large mass be kept fluid below, while it congeals at the surface, the crystallization there is much more distinct. When sulphur in complete fusion is poured into water, it becomes tenacious like wax, and may be applied (as is done by Mr. Tassie) to take impressions from engraved stones, &c. These impressions are quite hard, when the sulphur has become cold.

IV. At the temperature of about 290° Fahrenheit, sulphur is converted into vapour; and if this operation be conducted in close vessels, the volatilized sulphur is again collected in a solid form. This affords an example of the process of *sublimation*, which differs from distillation, in affording a solid product, while the latter yields a condensed liquid. In this mode, sulphur may, in part, be purified; and its purification is completed, by boiling it repeatedly in distilled water; then in twice or thrice its weight of nitro-muriatic acid, diluted with one part of distilled water; and, finally, by washing it with distilled water, till this comes off tasteless, and incapable of changing the blue colours of vegetables.

V. When flowers of sulphur are digested in alcohol, no union takes place; but if the two bodies be brought into contact, when both are in a state of vapour, they enter into chemical union. This may be shown by an ingenious experiment of La Grange, the apparatus for performing which are represented in the first plate of his "Manual." Into a glass alembic (see the plates to this work, fig. 2.) put a little sulphur; over this suspend, by a couple of strings, a small bottle filled with alcohol; and apply a receiver to the pipe of the alembic, the head being put into its place. Lute the junctures, and apply a gentle heat to the alembic. The sulphur will now be raised in vapour; and the vapour surrounding the bottle of alcohol, the latter will be volatilized, and will meet in this state the fumes of sulphur. A combination will take place between the two bodies, and sulphurized alcohol will pass into the receiver. On pouring this preparation into water, the sulphur will be precipitated.

VI. Sulphur is inflammable, and appears susceptible of two distinct combustions, which take place at different temperatures*. At 140° or 150° Fahrenheit, it begins sensibly to attract oxygen; and if the temperature be raised to 180° or 190°, the combination becomes pretty rapid, accompanied by a faint blue light. But the heat evolved is scarcely sensible; at least it is so weak, that the sulphur may thus be burnt out of gunpowder, and the powder be rendered useless, without inflaming it. At a temperature of 300°, its combustion, though still feeble compared with that of some other bodies, is much more active, and accompanied with a redder light. When set on fire in oxygen gas, it burns with a very beautiful and brilliant light; but of a given quantity of oxygen gas, it is not possible to condense the whole by this combustion, for reasons which hereafter will be stated. The product of these combustions, when examined, will be found to be sulphuric acid†.

SECTION II.

Sulphuric Acid.

I. Though this is not the mode in which sulphuric acid is ordinarily prepared (which will be afterwards described in chap. xii. sect. 4.), 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 alkalis. 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. 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. In 100 parts, it contains 61 sulphur and 39 oxygen.

(*b*.) It is nearly twice as heavy as water. This will appear from weighing a small phial filled with the acid, and afterwards

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* For an account of the oxides of sulphur, see Dr. Thomson's paper in Nicholson's Journal, vi. 101.

† Much sulphurous acid is also generated in these processes.

filled with distilled water. The same result will be more conveniently obtained, by making the comparison in the long-necked bottle. Plate i. fig. 14 The specific gravity of the acid, as prepared for purposes of commerce, is generally 1.85; but, it may be concentrated, by exposing it to heat, in a retort set in a sand-bath, so as to be of the specific gravity of upwards of 2.

(*c.*) In a pure state, it is perfectly limpid and colourless.

(*d.*) When mixed suddenly with water, considerable heat is produced. Four parts, by weight, of concentrated sulphuric acid, and one of water, when suddenly mixed together, each at the temperature of 50° Fahrenheit, have their temperature raised to 300°. This rise of temperature takes place, because the affinity or capacity of the compound of sulphuric acid and water for caloric, is less than that of the acid and water separately. 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, for ordinary purposes, should be conducted very gradually; and the acid should be added to the water 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. In one day, three parts of sulphuric acid, exposed to the atmosphere, are increased in weight one part; and one ounce, by twelve months exposure, has been found to gain an addition of 6¼.

(*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. To those, however, who have the means of repeating the process, and sufficient experience in chemical operations, the following instructions may be useful; especially as it is indispensable, in all experiments of research, to employ an acid thus purified.

The furnace, in which this process is conducted, should have a contrivance for supporting a sand-bath within it at a proper height; and an opening in the side, for transmitting the neck of the retort. (Plate vii. fig. 62, 63.) The retort must be coated with clay and sand over its whole body, and also over that part of the neck which is exposed to the fire. It is then to be placed, the coating being previously dry, in the sand-bath, about one-half filled with sulphuric acid; and a receiver must be applied, but not luted on. The fire must now be lighted, and raised with extreme caution. The first portion that comes over, amounting to about one-sixth, consists chiefly of water, and may be rejected. This is followed by the concentrated acid; and, at this period, there is great risk that the neck of the retort will be broken, by the contact of the condensed acid, which has a very high temperature, and which frequently cracks the glass, as effectually as the application of a red-hot iron. The fire must be regulated by the register-door of the ash-pit, so that several seconds may elapse between the fall of the drops into the receiver. The process may be continued as long as any acid is condensed. The retorts, employed for this purpose, should be most attentively annealed; and it is adviseable, that the operator should anneal them himself, by first heating them in an oven, and then allowing the oven to cool as slowly as possible.

Sulphuric acid 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 of sulphuric acid, changes it in the manner that has been pointed out.

(*h.*) In high temperatures, sulphuric acid is still further decomposed by combustible bodies.

1. Hydrogen gas, brought into contact with sulphuric acid, in a state approaching ignition, decomposes it, and water and sulphurous acid are formed. This, however, is a most dangerous and difficult process, which it is not adviseable to repeat. The decomposition of the acid may be safely effected in the following manner:

2. 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 experiment, 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, in the bottom of a broken Florence flask. 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 mercurial trough, to condense any sulphuric acid that may escape decomposition. (See pl. iii. fig. 31.) The gas thus obtained is termed, conformably to the principles of the new nomenclature, *sulphurous acid.*

SECTION III.

Sulphurous 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 above twice heavier than atmospherical air.

(*c.*) It extinguishes burning bodies, and kills animals.

(*d.*) It has the property of whitening or bleaching silk, and of giving it lustre.

(*e.*) Of sulphurous acid, water absorbs 33 times its bulk, or 1-11th of its weight, caloric is evolved, and the solution has the specific gravity 1.0513. From this fluid it is again separated, like carbonic acid, by the application of heat.

(*f.*) This watery solution does not redden infusion of litmus, as acids in general do, but totally destroys its colour. It restores the colour of sirup of violets, which has been reddened by other acids. (Nich. Journ. xvii. 303.)

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

(*h.*) Sulphurous acid is again converted to the state of sulphuric, by restoring oxygen to it.

1. A mixture of oxygen and sulphurous acid gases, both perfectly dry, and standing over mercury, is not diminished by remaining in contact during some months; but if a small quantity of water be added, the mixture begins to diminish, and sulphuric acid is formed.

2. To a portion of water saturated with this gas, add a little oxide of manganese, a substance that contains much oxygen loosely combined. The pungent smell of the water, and the other characteristics of sulphurous acid, will soon disappear.

3. Sulphurous acid gas is condensed into sulphuric acid by admixture with nitrous gas, and also by oxy-muriatic acid gas.

(*i.*) When the temperature of sulphurous acid gas is greatly reduced, by surrounding it with a mixture of snow and muriate of lime, it is changed into a liquid.

(*k.*) If sulphurous 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 alkalis.

(*l.*) It is decomposed, when submitted to the heat of ignition, in contact with certain combustible bodies. Thus, when a mixture of sulphurous acid and hydrogen gases are driven through a red-hot porcelain tube, the oxygen of the acid combines with the hydrogen, and forms water, and sulphur is obtained in a separate form. The sulphurous acid is decomposed, also, when transmitted over red-hot charcoal.

SECTION IV.

Combination of Sulphuric Acid with Alkalis.

ART. I.—*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 by a strong heat.

(*d.*) Water, at 60° of Fahrenheit, takes up only 1-16th of its weight; but boiling water dissolves one-fifth.

(*e.*) One hundred parts contain 30.21 acid, 64.61 alkali, and 5.18 water.

(*f.*) 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.

ART. II.—*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, three 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.

ART. III.—*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 has a cool bitter taste.

(*d.*) Two parts of water, at 60°, take up one of the salt, and boiling water dissolves its own weight. During solution, it produces cold; and also when mingled with powdered ice, or with snow.

(*e.*) The sublimed salt has an excess of acid; a portion of the base being expelled by the application of heat.

(*f.*) It contains, *per cent.* 55 acid, 14 ammonia, and 31 water.

(*g.*) It liquefies, 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.

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

ART. IV.—*Sulphate of Barytes.*

Barytes has a powerful affinity for sulphuric acid; and the combination of these two bodies may be effected with great facility

(*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 its solution 43,000 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.

(*g.*) By this process, carbonate of barytes may be procured, for the purpose of preparing the pure earth, and its various salts, when the native carbonate cannot be had in sufficient abundance. The sulphate is found, in considerable quantities, accompanying lead ore, in Derbyshire and other parts of England, where it is known by the name of cawk, ponderous spar, &c. When applied to the purpose of obtaining the carbonate of barytes, it is to be mixed with three or four times its weight of sub-carbonate of potash, and boiled with a proper quantity of water for a considerable time, in an iron kettle, stirring it, and breaking down the hard lumps, into which it is apt to run, by an iron pestle. It is then to be washed with boiling water, as long as this acquires any taste. On the addition of dilute muriatic acid, a violent effervescence will ensue, and a considerable portion of the earth, probably along with some metals, will be dissolved. To the saturated solution, add a small portion of pure ammonia. This will throw down any metals that may be present; and the barytes may afterwards be precipitated in the state of a carbonate, by a solution of carbonate of potash. Let the precipitated earth be well washed with distilled water; and, if the pure barytes is to be obtained from it, let it be treated as directed, chap. x.

(*h.*) Sulphate of barytes is also decomposed when ignited with powdered charcoal, which abstracts the oxygen of the sulphuric acid, and leaves a combination of sulphur and barytes. From this, the barytes may be removed by muriatic acid, as already directed, and the muriatic solution be decomposed by carbonate of potash.

(*i.*) The sulphate of barytes, when decomposed by charcoal, affords one variety of solar phosphorus. This phosphorus has been called, from the place where the sulphate is found from which it was first prepared, the Bolognian phosphorus. The native sulphate, powdered after being ignited, and finely sifted, is to be formed into a paste with mucilage of gum arabic, and divided into cylinders or pieces of one-fourth of an inch in thickness. These, after being dried in a moderate heat, are to be exposed to the temperature of a wind-furnace, placed in the midst of the charcoal. When the fuel is half consumed, it must be replenished, and suffered to burn out. The pieces will be found, retaining their original shapes, among the ashes, from which they may be separated by the blast of a pair of bellows. They must be preserved in a well-stopped vial.

This phosphorus, after being exposed a few minutes to the sun's rays, shines in the dark sufficiently to render visible the dial of a watch. This property is lost by repeated use, in consequence of the oxygenation of the sulphur; but may be restored by a second calcination.

(*k*.) Sulphate of barytes, when artificially formed and calcined, contains, *per cent.* 25 acid and 75 earth. The native sulphate, according to Klaproth, is composed of one-third acid and two-thirds base. (*Contributions*, i. 377.)

Art. v.—*Sulphate of Strontites.*

I. This salt resembles, very nearly, the sulphate of barytes. It may be formed in a similar manner, by pouring the solution of pure strontites into diluted sulphuric acid, or into the solution of an alkaline sulphate; for it has a stronger affinity than any of the alkalies for sulphuric acid. It is soluble in 3840 parts of boiling water.

II. The sulphate of strontites is also found native in considerable quantities; chiefly at Aust Passage, and at other places in the neighbourhood of Bristol. As the native carbonate is now becoming scarce, this compound may be advantageously employed for procuring artificial carbonate of strontites. The process is precisely similar to that already prescribed for decomposing the sulphate of barytes, (Art. iv. *g*.)

Art. vi.—*Sulphate of Lime.* [See Note 19.]

I. The sulphate of lime is formed, by adding to the carbonate a sufficient quantity of sulphuric acid; and by gently calcining the residue, to expel the redundancy of the latter acid. It is also found native, in great abundance, under the names of gypsum, plaster of Paris, &c.

II. It has the following properties:

1. It it insipid, and free from smell.

2. It is difficultly soluble, requiring 500 times its weight of cold water, or 450 of hot water.

3. It is fusible by a moderate heat. After calcination, it absorbs water rapidly, and forms a good cement.

4. It is decomposed by carbonates of alkali, a double exchange of principles ensuing. Hence the milkiness which ensues on adding carbonate of potash to most spring waters; the carbonate of lime, which is generated, being less soluble than the sulphate. Hence, also, hard waters, which always contain sulphate of lime in solution, curdle soap, the alkali of which is detached by the sulphuric acid, and the oil is set at liberty.

5. It is decomposed by ignition with charcoal, which separates the oxygen of the sulphuric acid, and leaves a combination of lime with sulphur.

ART. VII.—*Sulphate of Magnesia.*

I. When highly concentrated sulphuric acid is suddenly added to fresh-prepared and pure magnesia, prodigious heat and vapour are excited, and are accompanied frequently with an extrication of light. This appearance was first observed by Westrumb.

II. If the carbonate of magnesia be added to diluted sulphuric acid, the carbonic acid is expelled, and a solution of sulphate of magnesia is formed, which crystallizes on cooling. Crystals of sulphate of magnesia may also be procured in the shops, under the name of Epsom salt.

III. These crystals have the following properties :

1. They have the form of small quadrangular prisms, surmounted by quadrangular pyramids with dihedral summits.

2. At the temperature of 60°, this salt is soluble in an equal weight of cold water, and in three-fourths its weight of boiling water, which thus receives an addition of one-fourth to its bulk.

3. It effloresces in the air, and is slowly reduced to powder. When exposed to strong heat, it undergoes the watery fusion, but is not volatilized.

4. Its solution is precipitated by carbonates of potash and of soda ; but not by carbonate of ammonia, unless heat is applied. The carbonate of magnesia of the shops is prepared, by mixing together concentrated and hot solutions of carbonate of potash and sulphate of magnesia. The sulphate of potash, thus formed, is removed by copious washing with water, and the carbonate of magnesia is then dried. The proportions employed are filtered solutions of equal weights of the two salts, each in its own weight of boiling water.

5. When a dilute solution of carbonate of soda is mixed with a dilute solution of sulphate of magnesia, and the sub-carbonate which is formed, if any, is separated by filtration, crystals of carbonate of magnesia, after some time, shoot in the liquid, containing a larger proportion of carbonic acid, and already described, chap. x. sect. 4.

ART. VIII.—*Sulphate of Alumine.* [See Note 20.]

The properties of this salt may be exhibited by those of the common alum of commerce ; though, as will afterwards appear, alum is not merely a combination of this earth with sulphuric acid; but contains other ingredients. It has the following characters.

(*a.*) It has a sweetish astringent taste.

(*b.*) It dissolves in water, five parts of which, at 60°, take up one of the salt, but hot water dissolves about 3-4ths 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 alkali, that are added to a solution of sulphate of alumine, from occasioning any precipitate.

(*e.*) On a farther addition of alkali, the alumine is precipitated.

(*f.*) Sulphate of alumine, when heated, swells up, loses its regular form, and becomes a dry spongy 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, when cold, is to be finely powdered, and introduced into a common vial, coated with clay, to which a glass tube, open at each end, is to be luted, to allow the escape of the gases that are produced. The vial 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 vial. When cold, the tube may be removed, and a cork substituted in its place. The principal difficulty in the process, is to stop it precisely at the period, when the pyrophorus is formed; for if the heat be continued longer, the sulphur will be sublimed, and the preparation spoiled.

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

ART. IX.—*Sulphate of Glucine.*

Glucine combines readily with sulphuric acid, both in its pure and carbonated state. The resulting salt is extremely soluble; insomuch that, when evaporated, it assumes the form of a syrup, without crystallizing. Its taste is sweet, and rather astringent. It is decomposed entirely in a high temperature, the earth being left in a state of purity. It is also destroyed by ignition with charcoal. It does not yield its earthy ingredient to any of the acids; but is decomposed by all the alkalis and earths, alumine excepted.

ART. X.—*Sulphate of Zircon.*

To effect the combination of zircon with any acid, this earth should be fresh precipitated; for, after being dried, it enters with difficulty into union.

The salt, resulting from the union of sulphuric acid with zircon, is white, insoluble, and without taste. It is decomposed by a high temperature, which expels the acid, and leaves the zircon pure. It is not changed by other acids, but yields it sulphuric acid to the alkalis, and to most of the earths.

ART. IX.—*Sulphate of Yttria.*

Sulphuric acid readily dissolves yttria, and caloric is evolved during the process. As the solution goes on, the sulphate crystallizes in small brilliant grains, which have a sweetish taste, but less marked than that of the sulphate of glucine. Their colour is a light amethyst red. They require 30 parts of water, of the temperatue of 60°, for solution, and give up their acid when exposed to a high temperature. They are decomposed by oxalic acid, prussiate of potash, infusion of galls, and phosphate of soda.

SECTION V.

Sulphites.

I. The combination of sulphurous acid with alkaline and earthy bases, may be effected by passing the gas, as it proceeds from the materials (sect. 2. *h*), through the base, dissolved or diffused in water. An intermediate vessel may be placed, as represented, fig. 30 and 31, to condense any sulphuric acid that may pass over; and the solution of the alkali or earth may be contained in a bottle with two necks. Pure potash, soda, or ammonia, are readily kept in solution; but barytes or strontites must be dissolved in boiling water; and the bottle containing them must be surrounded with hot water, while the gas is transmitted through the solution. The solution, when saturated with gas, may be evaporated; and this is best done in an alembic, covered with its capital, because the salts of this class are changed by the action of the atmosphere.

II. The sulphites have no peculiarly interesting properties, that can entitle them to minute and specific description, in a work devoted solely to the students of chemical science. I shall enumerate, therefore, those properties only that belong to the whole class; and refer, for farther information, to the 2d and 24th volumes of the *Annales de Chimie*. Their general qualities are the following:

1. They have a disagreeable taste and smell, resembling that of the fumes of burning sulphur.

2. When heated, they emit sulphurous acid and water, and then sulphur, which, on the application of an inflamed substance, takes fire, and burns violently.

3. Exposed to the atmosphere, in a state of solution, they absorb oxygen, and are slowly changed into sulphates.

4. When added to nitric acid, red fumes arise, and the salts become sulphates. Oxygenized muriatic acid produces the same effect. Concentrated sulphuric acid expels sulphurous acid gas, which may be collected over mercury.

5. When perfectly pure, sulphites are not precipitated by a solution of pure barytes or strontites, or by any of the salts with base of either of those earths. If a precipitation ensue, it indicates the presence of a portion of sulphate.

SECTION VI.

Binary Compounds of Sulphur.—1st, With Alkalis.—2d, With Hydrogen.

ART. I.—*Sulphurets.*

I. The combination of sulphur, with the fixed alkalis and earths, may be formed by fusing together, in a covered crucible, equal parts of sulphur and the respective alkali or earth with which it is to be combined. The compound is to be poured, when in a state of fusion, into an iron dish, or upon a smooth stone; and preserved in a well-closed bottle. These compounds have, for the most part, a reddish brown, or liver colour; and hence were formerly called *hepars*, or *livers* of sulphur. They may be formed, also, by fusing the alkaline or earthy sulphates with powdered charcoal; but in this case, the sulphuret generally contains a portion of carbonic acid, and also of charcoal.

Sulphuret of lime, when intended for the purpose of *Canton's phosphorus*, is best prepared by placing, in a crucible, alternate strata of calcined and pounded oyster-shells and sulphur; exposing them to a moderate heat; and then confining them in a bottle with ground stopper. Or, according to the original directions of Canton, three parts of oyster-shells, calcined for about an hour and pulverised, are to be mixed with one of sulphur, and rammed tightly into a crucible, which is to be kept red-hot for about an hour. The compound, when cold, has the properties already assigned to the Bolognian phosphorus.

II. Sulphurets have the following properties:

(*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 alkalis.

(*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 alkali, 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 alkali will be 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 alkali with the respective acid employed.

(*e.*) The liquid sulphurets absorb oxygen gas. This may be shown by the experiments already described, (chap. v.) 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 alkali, 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.

Art. II.—*Sulphuretted Hydrogen Gas.*

I. 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.

II. Its properties are the following:

(*a.*) Its smell is extremely offensive, resembling that of putrefying eggs.

(*b.*) It is inflammable, and burns either silently or with an explosion, according 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 sulphurous acids from that of the oxygen and sulphur.

When three parts of sulphuretted hydrogen are mingled with two of nitrous gas, the mixture, on being inflamed, burns with a yellowish green flame.

(*c.*) It tarnishes silver, mercury, and other polished metals, and instantly blackens white paint.

(*d.*) It is absorbed by water, which takes up its own bulk, and thus acquires the peculiar smell of the gas. It is this gas which gives to the Harrogate, and some other natural waters, their disagreeable odour.

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

(*f.*) Water impregnated with sulphuretted hydrogen, when exposed to the atmosphere, becomes covered with a pellicle of sulphur. Sulphur is even deposited, when the water is kept in well-closed bottles.

(*g.*) On the addition of a few drops of nitric or nitrous acid to the watery solution, sulphur is instantly precipitated. In this case the oxygen of the acid combines with the hydrogen of the gas, and the sulphur is separated.

(*h.*) This gas, as will afterwards appear, is decomposed by mixture with oxygenised muriatic acid gas; and sulphur is precipitated.

(*i.*) It is decomposed also when kept in a state of mixture with atmospheric air, the oxygen of which combines with the hydrogen, and forms water, while the sulphur is precipitated.

(*k.*) When sulphuretted hydrogen gas and sulphurous acid gas are mingled together, the hydrogen of the former unites with oxygen of the latter, and the sulphur of both is precipitated.

(*l.*) It is decomposed when passed over ignited charcoal, and is converted into carburetted hydrogen gas.

(*m.*) Sulphuretted hydrogen, according to Thenard, is composed, in 100 parts, of 29 hydrogen, and 71 sulphur. One hundred cubic inches weigh 38.17. Mr. Kirwan states the weight of the same quantity, at the temperature of 60°, and under 30 inches pressure, at only 34.286 grains.

(*n.*) It precipitates, both in the state of a gas and of watery impregnation, all metallic solutions, excepting those of iron, nickel, cobalt, manganese, titanium, and molybdena.

(*o.*) It is copiously absorbed by alkalis, and by all the earths, excepting alumine and zircon. These alkaline and earthy combinations are termed hydro-sulphurets.

Art. III.—*Hydro-Sulphurets.*

In its union with alkaline and earthy bases, sulphuretted hydrogen seems to perform, in a great measure, the functions of an acid; and presents, therefore, an important exception to the doctrine of acidification; for, in this instance, a body, entirely destitute of oxygen, possesses some of the most important characters of an acid, viz. the property of changing vegetable blues to red, and of uniting with alkalis.

I. The hydro-sulphurets may be formed, by transmitting sulphuretted hydrogen gas, as it issues from the materials that afford it, through a solution of the alkaline or earthy base. Or the base, when insoluble, must be kept suspended in water by mechanical agitation.

II. The hydro-sulphurets have several qualities common to the whole genus.

1. They are all soluble in water, and the recent solution is colourless. By exposure to the air, however, it first becomes green, or greenish yellow, and deposits sulphur on the sides of the vessel. The glass bottle, containing the solution, becomes black on its inner surface, in consequence of the combination of sulphur with the oxide of lead contained in the glass.

2. After long exposure to the atmosphere, the solution entirely loses its colour, and again becomes perfectly limpid. When examined, it is found to consist of a combination of sulphuric acid with the peculiar base of the hydro-sulphuret. This is

owing to the absorption of oxygen, which all hydro-sulphurets take from the atmosphere; the formation of a sulphite; and the conversion of this, by farther oxygenation, into a sulphate. Hence, when confined in contact with a limited quantity of atmospherical air, hydro-sulphurets effect a diminution of volume; and may be employed to ascertain its proportion of oxygen. They entirely absorb pure oxgen gas.

3. When an acid is poured on any of the hydro-sulphurets, the sulphuretted hydrogen gas is disengaged. The acid employed should be one which strongly retains its oxygen, such as the sulphuric or muriatic; otherwise it will probably be decomposed. A hydro-sulphuret, which has been a few days exposed to the air, yields, by this treatment, sulphurous acid gas, along with sulphuretted hydrogen.

4. The solutions of hydro-sulphurets precipitate all metallic solutions. They also precipitate alumine and zircon from their solutions, but no other earths.

5. The hydro-sulphurets are, for the most part, susceptible of a regularly crystallized form.

The enumeration of these characters appears to me to be sufficient for the purposes of the general student.—More detailed information may be found in a memoir of Berthollet, in the 25th vol. of the *Ann. de Chim.*; and in an essay of Vauquelin in the 42d vol. of the same work.

ART. IV.—*Super-Sulphuretted Hydrogen, and Hydroguretted Sulphurets.*

Super-sulphuretted hydrogen is obtained, when hydro-sulphuret of potash is poured, by little and little, into muriatic acid. A very small portion only of gas escapes; and while the greater part of the sulphur separates, one portion of it combines with the sulphuretted hydrogen; assumes the appearance of an oil; and is deposited at the bottom of the vessel. Or dissolve sulphur in a boiling solution of pure potash; and into a vial, containing about $\frac{1}{3}$ its capacity of muriatic acid, of the specific gravity 1.07, pour about an equal bulk of the liquid hepar. Cork the vial, and shake it; the hydroguretted sulphur gradually settles to the bottom. Mr. Berthollet, jun. has, also, found that super-sulphuretted hydrogen is formed by bringing sulphur into contact with charcoal, heated to incandescence in a glass tube disposed as in fig. 40. *cc*. The product varies in its proportions, and is solid, liquid, or gaseous, according to the temperature in which it has been formed, the solid containing the largest quantity of sulphur, and the gaseous least. (See his memoir in Nich. Journ. xviii. 43.) Its properties are the following:

1. If gently heated, sulphuretted hydrogen gas exhales from it; the super-sulphuret loses its fluidity; and a residue is left, consisting merely of sulphur.

2. It combines with alkalis and earths; and forms with them a class of substances called hydroguretted sulphurets.

There are, therefore, three distinct combinations of sulphur and its compounds with alkalis and earths. The first consist, simply, of sulphur, united with an alkaline or earthy base, and are called strictly *sulphurets*. The second are composed of sulphuretted hydrogen, united with a base, and are called *hydrosulphurets*. The third contains super-sulphuretted hydrogen, attached to a base, and constitute *hydroguretted sulphurets*.

The sulphurets can exist, as such, only in a dry state; for the moment they begin to dissolve in water, a decomposition of that fluid commences; sulphuretted hydrogen is formed; and this, uniting with an additional dose of sulphur, composes super-sulphuretted hydrogen. This last, uniting with the base, forms an hydroguretted sulphuret. Hence the sulphurets are changed, by solution, into hydroguretted sulphurets.

II. The hydroguretted sulphurets are also formed by boiling, along with a sufficient quantity of water, the alkaline, or earthy base, with flowers of sulphur. Thus a solution of pure potash, pure soda, or of barytes or strontites, may be changed into hydroguretted sulphurets. To prepare this compound, with base of lime, the powdered earth, mixed with sulphur, may be boiled with a proper quantity of water, and the solution filtered. The hydroguretted sulphuret of ammonia (which base cannot, in strictness, owing to its liquid form, compose a true sulphuret) may be prepared as follows: Mix together, in a mortar, three parts of lime, fallen to powder in the air, and sifted, one part of muriate of ammonia, and one of flowers of sulphur. Introduce the mixture into a retort, and apply a receiver. Begin the distillation with a gentle heat. The first liquor, that comes over, has a light yellow tinge, and emits fumes; the second has a deeper colour, and is not fuming. When the latter begins to appear, the fire may be raised.

Another method of forming, by a very simple process, the hydroguretted sulphurets, consists in digesting, in a gentle heat, a hydro-sulphuret with powdered sulphur, an additional portion of which is thus dissolved by the sulphuretted hydrogen.

Hydroguretted sulphurets have the following properties.

1. They have a deep greenish-yellow colour; an acrid and intensely bitter taste, and an excessively offensive smell.

2. They deposit sulphur when kept in close vessels; become much more transparent and lighter coloured; and less offensive to the smell.

3. They rapidly absorb oxygen from the atmosphere, and from oxygen gas. Hence their employment in eudiometry. (See chap. v. sect. 4.)

4. On the addition of dilute sulphuric, or muriatic, or of certain other acids, they are decomposed. Sulphuretted hydrogen gas is evolved, and sulphur is precipitated.

The existence of a liquid *carburet of sulphur*, which was supposed, by Clement and Desonnes, to have been formed by the contact of sulphur with ignited charcoal, has been lately disproved by Mr. Berthollet, jun. (Nich. Journ. xviii. 43.) These two bodies appear, however, to form a solid compound.

CHAPTER XII.

COMBINATION OF AZOTE WITH OXYGEN, CONSTITUTING NITRIC ACID.....NITROUS GAS.....NITROUS OXIDE.....AND COMPOUNDS OF NITRIC ACID WITH ALKALIS.

SECTION I.

Nitric Acid.

I. 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 shock through a mixture of azotic and oxygen gases. The experiment is an extremely laborious one, and requires, for its performance, a powerful electrical machine; but those who are disposed to repeat it, may proceed as follows:

Let the tube, fig. 29, be filled with, and inverted in, mercury. Pass into it a portion of atmospherical air, or an artificial mixture of azotic and oxygen gases, in the proportion of 1 of the former to 2 of the latter.—Let an iron wire, lengthened out with one of platina, be introduced within the tube, so that the latter metal only may be in contact with the mixed gases; and let the end of this wire be distant about 1-4th of an inch from the extremity of the upper one. When the apparatus is thus disposed, pass a series of electric shocks through the gases for several hours. The mixture will be diminished in bulk; will redden litmus-paper when enclosed in it; and will exhibit distinctly the smell of nitrous acid. If the experiment be repeated, with the addition of a few drops of solution of potash, in contact with the gases, we shall obtain a combination of nitric acid with potash.

For all purposes of utility or experiment, however, nitric acid is prepared in a different manner, viz. by the decomposition of nitrate of potash, in a way which will presently be described.

II. The analysis of the acid may be obtained by driving its vapour through a red-hot porcelain tube (fig. 40. *cc*), and receiving the generated gases, which prove to be a mixture of azotic and oxygen gases.

III. The nitric acid has the following properties:

(*a.*) It is heavier than water, in the proportion of 1.5 to 1.

In its heaviest form, however, it still contains a portion of water. Pure nitric acid may be considered as a gaseous body, of the specific gravity, compared with common air, of 2440 : one hundred cubic inches at 55° Fah^{t} and under 30 inches pressure, weigh, according to Mr. Davy, 76 grains; or corrected to the temperature of 60° Fah^{t} they weigh 75.21 grains. The liquid acid consists of this gas condensed by water, of which it contains various proportions, as is shown by the following table of Mr. Davy.

TABLE

Of the Quantities of True Nitric Acid in solutions of different Specific Gravities.

100 parts Nitric Acid of Specific gravity.		True Acid*	Water
1,5040	contain	91,55	8,45
1,4475		80,39	19,61
1,4285		71,65	28,35
1,3906		62,96	37,04
1,3551		56,88	43,12
1,3186		52,03	47,97
1,3042		49,04	50,96
1,2831		46,03	53,97
1,2090		45,27	54,73

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[*] The quantities of oxygene and azote in any solution, may be thus found —— Let a=the true acid, x the oxygene, and y the azote.

Then $x=\frac{2.389\,a}{3.389}$ and $y=\frac{a}{3.389}$

(*b.*) Pure gaseous nitric acid, according to the same ingenious chemist, is composed of 29½ azote, and 70½ oxygen.

(*c.*) The watery solution is perfectly limpid and colourless.

(*d.*) It gives a yellow stain to the skin.

(*e.*) It boils at 248° Fahrenheit, and may be distilled over, without any essential change.

(*f.*) It absorbs moisture from the atmosphere ; and hence it increases in weight, and diminishes in specific gravity, by exposure to the air.

(*g.*) When two parts of the acid are suddenly diluted with one of water, an elevation of temperature is produced to about 112° Fahrenheit. When more water is added to this diluted acid, its temperature is reduced.

(*h.*) 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.

By exposing it to the sun's rays in a gas bottle, the bent tube of which terminates under water, oxygen gas may be procured.

(*i.*) This acid retains its oxygen with but little force.—Hence it is decomposed by all combustible bodies, which are oxygenized by it, with more or less rapidity in proportion to their affinity for oxygen.

1. When brought into contact with hydrogen gas at a high temperature, a violent detonation ensues. This experiment, therefore, requires great caution. 2. Poured on perfectly dry and powdered charcoal, it excites the combustion of the charcoal, which becomes red-hot, and emits an immense quantity of fumes. 3. It also inflames essential oils (as those of turpentine and cloves), when suddenly poured on them. In these experiments, the acid should be poured out of a bottle, tied to the end of a long stick ; otherwise the operator's face and eyes may be severely injured. 4. Nitric acid is decomposed, by boiling it in contact with sulphur, which attracts the oxygen, and forms sulphuric acid.

(*k.*) 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 oxydized.

(*l.*) 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, or nitric oxide.

SECTION II.

Nitrous Gas, or Nitric Oxide. [See Note 21.]

The properties of this gas are the following:

(*a.*) It is permanent over water; but it is absorbed in small quantity, when agitated with water which has been recently boiled, and has become cold. (See the Table in the Appendix.) This solution, according to La Grange (vol. i. p. 131), is converted, by long keeping, into nitrate of ammonia, in consequence of the decomposition of the water.

Nitrous gas is rather heavier than common air, 100 cubic inches at 55°, barometer 30, weigh 34.26, or at 60° Fah^{t} 33.80 grains. (Davy.)

(*b.*) When well washed with water, it is not acid. It will be found not to redden the colour of litmus. This may be shown by introducing a piece of paper, tinged with that substance, into a jar of nitrous gas, standing inverted over water. To accomplish this, the paper should be fastened to the end of a glass rod or a piece of stick. The colour will remain unchanged.

(*c.*) It extinguishes flame, and is fatal to animals. Homberg's pyrophorus, however, is inflamed by it; and charcoal and phosphorus, introduced into it when in a state of actual combustion, continue to burn vehemently.

(*d.*) Mingled with hydrogen gas, it imparts a green colour to its flame.

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

(*f.*) The same appearances ensue, less remarkably, with atmospheric air; and the diminution is proportionate to the quantity of oxygen gas which it contains. On this principle, of its condensing oxygen, 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, in its employment in this mode, have hitherto been considered such, as to forbid our relying implicitly on the results which it may afford. Learning, however, from Mr. Dalton, that he constantly employs nitrous gas in determining the purity of air, and with perfect satisfaction as to the accuracy of his results, I have obtained from him the following communication; and have had, since receiving it, such abundant experience of the facility, quickness, and accuracy of the method, that I now prefer it to every other. It may be necessary to premise, that for applying nitrous gas to this purpose, two tubes will be found convenient, shaped like fig. 24.; each from 3 to 4 tenths of an inch in diameter; 8 or 9 inches long, exclusive of the funnel-shaped part; and accurately graduated into minute aliquot parts. What these parts are, is of no consequence. Hundredth parts of a cubical inch give rather too large divisions of the scale; but if each of these be divided into two, the scale will be sufficiently small. If the tube employed be not long enough to comprise 100 of these parts, the experiment may be made on 50 parts only of atmospherical air; and the results, multiplied by 2, will give the proportion in 100 parts.

" To use nitrous gas accurately in eudiometry, it is only re- " quisite to take both gases in a dilute state, namely, containing " three or four times their bulk of azotic gas (which atmospheric " air naturally does), or of any other gas not acted upon by ni- " trous or oxygen gases. In this case, if an excess of one gas " be used, the other is, in a few minutes, entirely taken up, and " in a constant proportion; whatsoever may be the form of the " vessel, or the manner of mixing the gases. The proportion " is 1 of oxygen to 1.7 of nitrous, so that 10-27th of the diminu- " tion over water are oxygen, and 17-27th nitrous gas. It is " proper, as soon as the greater part of the diminution has en- " sued, to transfer the mixture through water into a graduated " vessel, without using any agitation.

" If pure nitrous gas be admitted to pure oxygen gas in a nar- " row eudiometer tube, so that the oxygen gas is uppermost, the " two unite very nearly in the same uniform proportion as above. " If, on the other hand, the nitrous be the upper gas, a much " less quantity of it disappears, viz. 1.24 nitrous to 1 oxygen. " If undiluted nitrous gas be admitted to pure oxygen gas in a " wide vessel over water, the whole effect takes place imme- " diately; and one measure of oxygen will condense 3.4 ni- " trous gas.

" To render this rule more intelligible, an example may be " necessary. Let 100 measures of common air be admitted to " 100 measures of a mixture of nitrous gas with an equal pro- " portion of azotic or hydrogen gas. After standing a few mi- " nutes in the eudiometer, there will be found 144 measures. " The loss 56 being divided by the common divisor, 2.7, gives " 21 nearly for the oxygen gas present in 100 measures of com- " mon air."

To these directions I may add, that when atmospherical air is the subject of experiment, it is scarcely necessary to dilute the nitrous gas, with any other gas, previously to its use. If a number of experiments be made, it will be proper, in all cases, to let the gases remain together a definite time (say 10 minutes) before noting the diminution; and it is needless to transfer them into another vessel. If the mixed gas, under examination, contain much more oxygen, than is present in atmospherical air, then it is proper to dilute the nitrous gas with an equal bulk of hydrogen gas; and, in this case, the narrower the tube, in which the experiment is made, the more accurate will be the result.

(*g.*) 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.

(*h.*) 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 gases, 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.

(*i.*) 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 acid.

According to Dr. Priestley, 100 parts of nitric acid, of the specific gravity of 14 to 10, absorb, in two days, 90 parts by weight of nitrous gas*. When about seven parts of gas have been absorbed, the acid acquires an orange colour; when 18 have been absorbed, it becomes green; and the whole quantity, which it is capable of condensing, changes it into a liquor, which emits an immense quantity of red fumes. The gas, thus absorbed, is mostly separated again on dilution with water.

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

(*l.*) Nitrous gas is decomposed by exposure to bodies that have a strong affinity for oxygen. Thus, iron-filings decompose it, and become oxydized, affording a proof of the presence of oxygen in this gas.

During this process, water, ammonia, and nitrous oxide are generated. Sulphuret of potash, &c. have a similar effect. Mixed with sulphurous acid, it is decomposed, and this acid is changed into the sulphuric. (Nich. xvii. 43.)

(*m.*) Nitrous gas is absorbed by the green sulphate and muriate of iron†, which do not absorb azotic gas. To ascertain, therefore, how much azotic gas a given quantity of nitrous gas contains, let it be agitated in a graduated tube with one of these solutions. This information is necessary, previously to deducting, from its effects on atmospheric air, the proportion of oxygen gas.

From the important use which is now made by some chemists 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

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* Priestley on Air, 2nd edit. i. 383. In the experiment alluded to, 1-5th of an ounce measure of nitric acid absorbed 130 ounce measures of nitrous gas. There is reason, however, to suspect some inaccuracy in the experiment; for, according to Mr. Davy, 100 parts of nitric acid, after having absorbed all the nitrous gas which it is capable of condensing, hold only 9 or between 9 and 10 parts in combination.

† For on account of these salts, see chap. xviii. sect. 6.

iron, in order to ensure the perfect saturation of the acid. Fill a 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 inverted bottle frequently. The colour of this solution will change to black, and the production of gas and the 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. The most commodious method of applying this solution, is by means of Dr. Hope's eudiometer, already described. (Chap. v. sec. 4.)

(*n*.) A very interesting experiment, affording a synthetic proof of the constitution of nitrous gas, we owe to Dr. Milner, of Cambridge*. In an earthern tube, about 20 inches long and 3-4th 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 to each other, (fig. 40.) 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, which may terminate in a two-necked empty bottle. To the other neck of the bottle, lute a glass tube, bent so as to convey any gas that may be produced, under the shelf of the pneumatic trough. 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 alkali will be decomposed; its hydrogen, uniting with part of the oxygen which is 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.

(*o*.) Nitrous gas is stated, by Mr. Davy, to consist of 56 oxygen and 44 azote.

(*p*.) 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.

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* Phil. Trans. 1789.

† See his Comparative View of the Phlogistic and Antiphlogistic Theories, 2nd edition, page 300, note.

In this experiment, the tin, at the same instant, attracts the oxygen both of the nitric acid and of the water. Hydrogen and azote are consequently set at liberty; and, before they have assumed the gaseous state, these two bases combine, and constitute ammonia. The ammonia, thus generated, unites with a portion of undecomposed nitric acid; and is disengaged from this combination by potash or lime, which render it evident to the smell.

SECTION III.

Gaseous Oxide of Azote—Nitrous Oxide of Davy. [See Note 22.]

I. This compound, also consisting of oxygen and azote, but in different proportions from those of nitrous gas, 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 nitrous oxide.

Some nicety and experience are required to suspend the decompostion before it has gone too far; in which case azotic gas is obtained. The sulphite of potash, being incapable of decomposing nitrous oxide, is best adapted to the conversion of nitrous gas into that elastic fluid. The process, in all cases, may be suspended, when about two-thirds the original bulk of the gas are left.

(*b.*) By dissolving zinc, or tin, in nitric acid, diluted with five or six times its weight of water. Zinc, during this solution, disengages nitrous oxide till the acid begins to exhibit a brownish colour, when the process must be suspended, as nitrous gas is then formed. But by neither of these processes is the gas obtained sufficiently pure for exhibiting its qualities. To procure it in a state of purity, the following process is the best adapted.

(*c.*) To nitric acid, diluted with five or six parts of water, add carbonate of ammonia, till the acid is saturated. Then evaporate the solution; and, to supply the waste of alkali, add, occasionally, a little more of the carbonate. Let the solution be evaporated by a very gentle heat. The salt obtained, when the solution has cooled, is next to be put into a glass retort, and distilled with a sand-heat, not exceeding 440 Fahrenheit*. The heat of an

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* From the observations of Mr. Sadler (Nicholson, xv. 286.), it appears that the purity of the nitrate of ammonia is of considerable importance; and that its adulteration with muriate diminishes the quantity, and impairs the quality of the gas.

Argand's lamp is more than sufficient, and requires cautious regulation. The salt will presently liquefy, and must be kept gently simmering, avoiding violent ebullition. The gas may be collected over water, and allowed to stand a few hours before it is used, during which time it will deposit a white cloud, and will become perfectly transparent.

A gazometer is best adapted for its reception; because all danger is then avoided of an absorption of the water of the trough into the retort; and because the gas is brought into contact with a much smaller surface of water, which has the property of absorbing a considerable proportion of the gas. On this account, water, which has been once used to confine the gas, may be kept for the same purpose.

The changes that take place, during the conversion of nitrate of ammonia into nitrous oxide, are the following: Nitric acid is composed of oxygen and nitrous gas; ammonia, of hydrogen and azote. In a high temperature, the nitrous gas combines with an additional dose of azote, and forms nitrous oxide; while the oxygen of the decomposed nitric acid unites with the hydrogen of the ammonia, and forms water.

The gas, thus obtained, was termed, by the Society of Dutch chemists, gaseous oxide 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 oxide.*

In order to ascertain whether nitrous oxide be adulterated with either common air or oxygen gas, we may mix equal measures of the gas under examination, and of nitrous gas. If any diminution ensue, the presence of one of these may be suspected; and the amount will show which of them is contained in it. Nitrous gas, however, is a much more common contamination; for it is generated, along with nitrous oxide, whenever the temperature of the salt is raised too high. Its presence may be detected, either by a diminution on the admixture of oxygen gas; or by an absorption being effected, on agitating the gas with a solution of green sulphate of iron, which has no action on pure nitrous oxide. (See also p 159, *g*.)

II. This gas has the following properties:

(*a*.) It is considerably heavier than common air. About 55° Fah^t and 30 inches pressure, 100 cubic inches weigh 50.20 grains, or under the same pressure, and at 60° Fah^t 49.68. (Davy.)

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

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

(*c.*) Phosphorus, introduced into it in a state of inflammation, burns with increased splendour.

Phosphorus, however, may be melted, and sublimed in this gas, without alteration. It may even be touched with a red-hot iron wire, without being inflamed; but when a wire, intensely heated, or made white-hot, is applied, the phosphorus burns, or rather detonates, with prodigious violence.

(*d.*) Sulphur, introduced into nitrous oxide when burning with a feeble blue flame, is instantly extinguished; but when in a state of an active inflammation, it burns with a vivid and beautiful rose-coloured flame.

(*e.*) Red-hot charcoal burns in it more brilliantly than in the atmosphere.

(*f.*) Iron wire burns in this gas with much the same appearance as in oxygen gas, but for a shorter period.

(*g.*) Nitrous oxide is rapidly absorbed by water that has been previously boiled, about 1-30th the original bulk of the gas remaining uncondensed. (See Table.) A quantity of gas, equal to considerably more than half the bulk of the water, may be thus made to disappear. This property furnishes a good test of the purity of nitrous oxide; for the pure gas is almost entirely absorbed by boiled water, which has cooled without the access of air. The water employed should exceed the gass three or four times in bulk.

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

(*i.*) The impregnated water does not change blue vegetable colours.

(*k.*) It has a distinctly sweet taste, and a faint, but agreeable, odour.

(*l.*) It is not diminished by admixture with either oxygen or nitrous gas.

(*m.*) A mixture of this gas with hydrogen gas detonates loudly, on applying a lighted taper, or passing an electric spark.

When the proportion of hydrogen is nearly equal to that of nitrous oxide, or as 39 to 40, azotic gas only remains after the explosion; but when the proportion of hydrogen is smaller, nitric acid is also generated.

(*n.*) Nitrous oxide is not absorbed by alkalis; but if it be brought into contact with them, when in a nascent state, or before it has assumed the condition of a gas, it then enters into combination with alkaline bases. Thus, when a mixture of sulphite of potash and pure potash is exposed to nitrous gas, the latter is disoxygenized by the sulphite, and changed into nitrous oxide, which unites with the alkali. We obtain, therefore, a mixture of sulphate of potash with a compound of nitrous oxide and alkali, the former of which may be separated by priority of crystalization. The latter is composed of about three parts of alkali, and one of nitrous oxide. It is soluble in water; has a caustic taste, of peculiar pungency; and converts vegetable blues to green. Powdered charcoal, mingled with it, and inflamed, burns with bright scintillations. The nitrous oxide is expelled from fixed alkalis by all acids, even by the carbonic.

(*o.*) Animals, when wholly confined in this gas, die speedily.

(*p.*) One of the most extraordinary properties of this gas is exhibited by 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 constitutions; 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.

(*q.*) 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.

SECTION IV.

Nitrates.

ART. I.—*Nitrate of Potash.*

I. 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.

For the purposes of experiment, however, the nitrate of potash, which may be met with in the shops, and which is an abundant product of nature, may be employed on account of its greater cheapness.

II. 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 Fahrenheit; and boiling water takes up its own weight.

These are the proportions assigned by Bergman; but La Grange asserts, that of water, at the ordinary temperature, nitrate of potash requires only three or four times its weight for solution; and half its weight of boiling water. (*Manuel*, 1st edition, i. 243.)

(*c.*) By the application of a moderate heat it fuses, and being cast in moulds, forms what is called Sal Prunelle.

(*d.*) 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, oxygen 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 purposes of accuracy.

(*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 alkalis. 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 in a high temperature. 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 gases. Part of the carbonic acid also remains attached to the residuary alkali, and may be obtained from it on adding a stronger acid.

This residue was termed, by the old chemists, *clyssus* of nitre.

(*g.*) Nitrate of potash is also decomposed by sulphur, and with different results according to the temperature and proportions employed.

1. 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, ch. xi. sec. 4.

2. Mix a portion of sulphur with 1-6th or 1-8th its weight of nitrate of potash; [See Note 23.] put the mixture into a tin cup, and raise it, by a proper stand (fig. 25.), a few inches above the surface of water, contained in a flat shallow dish. Set fire to the mixture, and cover it with a bell-shaped receiver. In this case, also, sulphuric acid will be formed; but it will not combine, as before, with the alkali of the nitre, which alkali is present in sufficient quantity to absorb only a part of the acid produced. The greater part of the acid will be condensed on the inner surface of the glass bell, and by the water, which will thus become intensely acid. The operation may be repeated three or four times, using the same portion of water. When the water is partly expelled, by evaporation in a glass dish, concentrated sulphuric acid remains, which has been formed by the union of the oxygen of the nitre, and that of the atmospherical air, with the sulphur submitted to experiment*. By a process of this kind, but on a large scale, and in extensive leaden chambers, the sulphuric acid of commerce is prepared.—The dilute acid, resulting from the union of the condensed vapour of the burning materials, with the stratum of water at the bottom of the chamber, is first boiled down in part in shallow leaden vessels, and is then transferred into glass retorts, where it is further concentrated by the continued application of heat.

(*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

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* In a Memoir of Clement and Desormes, published in Nicholson's Journal, xvii. 41, it is proved, as I have long believed, that the nitre does not furnish nearly the whole of the oxygen, required for the conversion of sulphur into sulphuric acid, but that a great part of the oxygen is derived from the atmospherical air of the chamber.

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 decomposed by sulphuric acid, which combines with the potash, and expels the nitric acid. Put into a glass retort, which may be either tubulated or not, four parts of nitrate of potash, reduced to a coarse powder, and pour upon it three parts of concentrated sulphuric acid. Apply a tubulated receiver, of large capacity, between which, and the retort, an adopter may be interposed; these junctures being luted with a mixture of pipe-clay, sifted sand, and cut tow or flax.—To the tubulure of the receiver, a glass tube may be fixed by means of the fat lute, and may terminate in another large receiver, containing a small quantity of water. If the operator wishes to collect the gaseous products also, this second receiver should be provided with a tubulure, to which a bent pipe may be luted, terminating under one of the inverted funnels in the shelf of the pneumatic trough. Apply heat to the retort, through the intervention of a sand bath. The first product that passes into the receiver, is generally of a red colour, and of a smoking quality. These appearances lessen more and more; and if the materials used were clean, the acid will come over pale, and even colourless. Afterwards it gradually re-assumes a red colour, and smoking property; which appearances go on increasing till the end of the operation; and the whole product, mingled together, has either a yellow or an orange colour, according to the temperature employed.

In the large way, and for purposes of the arts, it is usual to substitute earthen or cast-iron retorts, made extremely thick, for those of glass. An earthen head is adapted, and this is connected with a range of proper condensors. The strength of the acid is varied also, by putting more or less water into the receiver.

Nitric acid, obtained by this process, is never perfectly pure. It contains, generally, both sulphuric and muriatic acids; the former of which is indicated by a white precipitate, on adding a solution of nitrate of barytes; and the latter, by a milkiness produced by nitrate of silver. The sulphuric acid may be separated, either by a second distillation from a portion of very pure nitre, equal in weight to 1-8th of that originally employed, or by adding nitrate of barytes ; allowing the precipitate to settle ; decanting the clear liquid, and distilling it. Muriatic acid is separated by the addition of nitrate of silver. An immediate milkiness ensues, and fresh additions must be made of nitrate of silver, as long as it occasions this appearance. Then allow the precipitate to subside ; decant the clear liquid, and re-distil it; leaving 1-8th or 1-10th in the retort. The product will be pure nitric acid. Nitrate of lead may be substituted for nitrate of silver. (See Nich. Journ. xi. 134.)

The nitric acid may also be obtained free from muriatic acid, if a perfectly pure nitrate of potash be employed for distillation. This purification is, in a great measure, effected by repeated solution of the nitre, in boiling distilled water, and crystallization. Finally, re-dissolve the crystals in warm distilled water, and add nitrate of silver as long as any precipitate appears. Allow this to settle, or separate it by filtration. The next product of crystals will be perfectly pure. The precipitated silver must not be thrown away, but must be washed with distilled water, dried, and preserved for the recovery of the silver, by a process to be hereafter described.

Nitric acid obtained in this manner is deficient also in another respect; for it is not perfectly oxygenated, but holds in solution a considerable quantity of nitrous gas, and hence is in the state rather of nitrous than nitric acid. To convert the former into the latter, put the acid into a retort, to which a receiver is applied, the two vessels not being luted, but joined merely by paper. Apply a very gentle heat for several hours to the retort, changing the receiver as soon as it becomes filled with red vapours. The nitrous gas will thus be expelled, and the acid will remain in the retort in a state of purity, and as limpid and colourless as water. It must be kept in a bottle secluded from the light.

One hundred parts of nitrate of potash, according to La Grange, yield by this process 43 of acid, or, according to my experience, above 50. This, however, is not the whole of what was contained in the salt: for a part is decomposed by the temperature necessary to the operation. Accordingly, a large quantity of oxygen gas is disengaged during the distillation, and may be collected by an obvious addition to the apparatus.

In the retort, there remains a compound of potash with more sulphuric acid than is essential to its saturation, or a super-sulphate of potash. On submitting this to a pretty strong heat, the excess of sulphuric acid is expelled ; and the residue, dissolved and evaporated, affords crystallized sulphate of potash.

Art. II.—*Nitrate of Soda.*

I. This salt may be formed, by saturating carbonate of soda with nitric acid; or by distilling common salt with three-fourths its weight of nitric acid. When the former process is adopted, the solution must be evaporated, till a pellicle appears on its surface, and then allowed to cool. Crystals will be produced, having the shape of rhomboids, or rhomboidal prisms.

II. These crystals have a taste like that of saltpetre, but more intense. They are soluble in three parts of water at 60°, and in less than an equal weight of boiling water. They attract moisture from the atmosphere. In other respects, in the means by which their decomposition is effected and its results, they agree with the nitrate of potash. The only use of nitrate of soda is, perhaps, that which has been suggested by Proust, who has found it to be more economical in the making of fire-works than nitrate of potash. (Nicholson, xv. 262.)

Art. III.—*Nitrate of Ammonia.*

I. The most simple mode of preparing this salt is by adding carbonate of ammonia to dilute nitric acid, till saturation has taken place. If the liquor be evaporated, by a heat between 70° and 100°, to a certain extent, it shoots, on cooling, into crystals, having the shape of six-sided prisms, terminated by long six-sided pyramids. Evaporated at the temperature of 212°, it yields, on cooling, thin fibrous crystals; and when the evaporation is carried so far, that the salt immediately concretes on a glass rod by cooling, it then forms a compact and shapeless mass.

II. The solubility of this salt varies, according to the temperature in which it has been formed. When in crystals, it requires twice its weight of water, for solution, or half its weight of boiling water. It deliquiates, in all its forms, when exposed to the atmosphere.

III. The most important property of this salt is the one which has been already described, viz. of yielding, when decomposed by heat, the nitrous oxide. One pound of the compact kind gives, by careful decomposition, nearly five cubic feet of gas, or rather more than 34 doses; so that the expense, estimating the salt at 5s. 10d. the pound, is about 2d. for each dose.

IV. In a temperature of 600° this salt explodes, and is entirely decomposed. Hence it was formerly called *nitrum flammans.*

V. Its composition varies according to the mode of its preparation, and is stated by Mr. Davy as follows:

Prismatic.	Fibrous.	Compact.	
69.5	72.5	74.5	acid
18.4	19.3	19.8	ammonia
12.1	8.2	5.7	water
100	100	100	

Art. iv.—*Nitrate of Barytes.*

I. Nitrate of barytes may be prepared, by dissolving either the artificial or native carbonate in nitric acid, diluted with 8 or 10 parts of water. If the artificial carbonate be employed, it should be previously well washed with distilled water, till the washings cease to precipitate nitrate of silver. A solution of nitrate of barytes, mixed with one of silver, should continue perfectly transparent. On evaporation, it yields regular octahedrons, often adhering to each other in the form of stars; and sometimes it is obtained in small brilliant plates. It requires for solution 12 times its weight of water at 60°, and three or four parts of boiling water. It is not altered by exposure to the air. In a red-heat, its acid is decomposed, and the earth remains pure. This furnishes another method of procuring pure barytes; but the heat must not be carried too far, otherwise the barytes is apt to vitrefy with the crucible. The residue, on the addition of water, dissolves with great heat and noise, and the solution, on cooling, yields crystals of pure barytes.

Art. v.—*Nitrate of Strontites.*

This salt may be obtained in the same manner as the nitrate of barytes, with which it agrees in most properties. The solubility of its crystals, however, differs considerably; for they are dissolved by their own weight of water at 60°, or by little more than half their weight of boiling water. When applied to the wick of a candle, or added to boiling alcohol, they communicate to the flame a deep blood-red colour. They are decomposed by a high temperature, and afford pure strontitic earth.

Art. vi.—*Nitrate of Lime.*

This salt is found abundantly in the cement of old buildings, which have been long inhabited by man, or other animals. To prepare it artificially, nitric acid, diluted with five or six parts of water, may be saturated with carbonate of lime. When this solution is boiled down to the consistence of syrup, and exposed in a cool place, long prismatic crystals are formed, resembling, in their disposition, bundles of needles diverging from a common centre. These crystals are readily soluble in water, of which, at 60°, they require two parts, and boiling water dissolves an equal weight. They deliquiate speedily, when exposed to the air; and are decomposed at the temperature of ignition.

When a solution of nitrate of lime is evaporated to dryness in an earthen vessel, then fused for five or ten minutes in a crucible, and poured, while in fusion, into an iron pot previously heated, the congealed mass forms *Baldwin's phosphorus.* It must be broken into pieces, and preserved in a well-stopped vial. These pieces, after having been exposed to the sun for a few hours, emit in the dark a beautiful white light, affording one variety of solar phosphorus.

Art. vii.—*Nitrate of Magnesia.*

This compound may be prepared, by dissolving carbonate of magnesia in diluted nitric acid. The solution, when evaporated, yields crystals in the shape of prisms, with four oblique faces truncated at their summits. Most commonly, however, it forms a shapeless mass, consisting of an immense number of small needle-shaped crystals, crossing each other irregularly. These crystals deliquiate in the air, and are soluble in half their weight of water. When exposed to the heat of ignition, they fuse; a few bubbles of oxygen gas first escape; and the nitric acid then passes undecomposed.

Art. viii.—*Nitrate of Alumine.*

This salt is but little known. It may be formed by the solution of fresh precipitated alumine, which has been well-washed with distilled water, but not dried, in diluted nitric acid, with the assistance of heat. The solution, which has always an excess of acid, after evaporation, crystallizes in thin ductile plates. The crystals are extremely soluble; and, on the application of a high temperature, abandon their acid. They are decomposed by most alkalis and earths. Pure potash, added in excess, redissolves the precipitate.

ART. IX.—*Nitrate of Glucine.*

The nitrate of glucine is a sweet-tasted salt, which cannot be brought to crystallize. When evaporated to a dryness, it rapidly absorbs moisture from the atmosphere. It is soluble in alcohol. A high temperature decomposes it, without effecting its previous fusion.

ART. X.—*Nitrate of Zircon.*

The nitric acid dissolves, but cannot be saturated with, fresh precipitated zircon. The solution has always an excess of acid. When evaporated, it forms a yellowish transparent mass, extremely tenacious and viscid, and difficultly dried. It has a styptic astringent taste, and leaves on the tongue a thick substance, in consequence of its partial decomposition by the saliva. This dry nitrate is extremely soluble. The solution is decomposed by sulphuric acid, and by carbonate of ammonia, which throw down a precipitate soluble in an excess of the acid, or of the carbonate. Tincture of galls forms a white precipitate, which is soluble in an excess of the tincture.

ART. XI.—*Nitrate of Yttria*

May be prepared by dissolving yttria in nitric acid. The solution has a sweetish astringent taste; and, in most properties, resembles nitrate of glucine. It can scarcely be obtained in crystals; and if too great a heat be applied during evaporation, the salt becomes soft, assumes the appearance of honey, and concretes, on cooling, into a hard stony mass. Exposed to the air, it attracts moisture, and is resolved into a liquid.

SECTION V.

Nitrites.

The direct combination of nitrous acid with alkalis and earths cannot be effected: for this acid, consisting of nitric acid with a redundancy of nitrous gas, is decomposed during all these combinations, the nitrous gas escapes, and the result is a compound of nitric acid with the base employed. The only mode of obtaining nitrites, is to deprive the acid, contained in the nitrates, of part of its oxygen, by exposure for a short time to the temperature of ignition. This method, it must be obvious, cannot be used with those nitrates that abandon their acid on the application of heat, or which, like nitrate of ammonia, are more completely decomposed.

Nitrate of potash, after fusion in a crucible, becomes a nitrite of that alkali. It has a smell, when powdered, of nitrous gas. When diluted nitric acid, or even acetic acid, is poured upon it, vapours of nitrous acid are disengaged; and hence it appears, that the affinity of this acid for its base is weakened by dis-oxygenation; for no such effect arises on adding these acids to the nitrate. The solution of the salt in water changes the syrup of violets to green. Its other properties are little known.

CHAPTER XIII.

MURIATIC ACID, AND ITS COMBINATIONS WITH ALKALIES.

SECTION I.

Muriatic Acid. [See Note 24, and additions at the end.]

I. 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.

To obtain muriatic acid gas, let the tubulated gas-bottle (plate ii. fig. 17.) be about one-fourth, or one-third, filled with muriate of soda (common salt), which has been dried, on an earthen dish or plate, in an oven. To this adapt the acid-holder, filled with concentrated sulphuric acid; and let the aperture of the bent pipe terminate under a jar filled with, and inverted in, quicksilver. Open the communication between the acid and the salt, by turning the cock; and immediately on the contact of these two bodies, an immense quantity of muriatic acid gas will be disengaged. The first portions, that come over, may be allowed to escape, by holding the gas-bottle under a chimney; because they are contaminated by the admixture of the common air present in the bottle. The subsequent portions may be preserved for use; and the pure gas will exhibit the following qualities:

(*a.*) It has a very pungent smell; and is sufficiently caustic to blister the skin, when applied to it for some time.

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

(*c.*) It extinguishes a lighted candle. Before the flame goes out, the upper part of it assumes a greenish hue, the cause of which has not yet been explained. A white vapour also surrounds the extinguished wick, owing to the combination of water, produced by the combustion of the candle, with the muriatic acid gas.

(*d.*) It is heavier than common air, in the proportion of 173 to 100.

(*e.*) It effects the liquefaction of a piece of ice, almost as rapidly as a red-hot coal.

(*f.*) 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. According to Mr. Kirwan, an ounce-measure troy of water absorbs 800 cubical inches (i. e. 421 times its bulk, or its own weight) of muriatic acid gas; and the water, by this absorption, is increased about one-third its original volume. Dr. Thomson's experiments indicate a still larger absorption, viz. 515 cubical inches, or 308 grains by one cubic inch, equal to 252 grains, of water, at 60° Fahrenheit; the barometer standing at 29.4.

(*g.*) Muriatic acid gas is not decomposed by being transmitted over red-hot charcoal, nor by a succession of electrical shocks. The action of electricity, however, evolves a small portion of hydrogen gas, proceeding from the water which the acid gas holds in combination. From an estimate, founded on this experiment, I have inferred, that 100 cubic inches, or 60 grains of muriatic acid gas, after being dried by muriate of lime, hold in combination 1.4 grain of water.—Phil. Trans. 1800.

To prepare the liquid muriatic acid, the following process may be employed.

Into a tubulated retort, placed in a sand-bath, put eight parts of dried muriate of soda; and, to the tubulure, lute the bent tube (fig. 26. *a*) with fat lute. To the neck of the retort, affix a tubulated receiver (fig. 30. *b*) by means of the same lute; and to the aperture of this adapt a tube, twice bent at right angles, and furnished with Welter's contrivance for preventing absorption (fig. 31. *b*), the longer leg of which terminates beneath the surface of water contained in a two-necked bottle. From the other neck, let a second right-angled pipe proceed; and this may terminate in a similar manner, in a second bottle containing water. Let the junctures be all carefully luted; and, when they are sufficiently hardened, pour very gradually through the bent tube five parts by weight of strong sulphuric acid, making the additions at several distant intervals. On each affusion of the acid a large quantity of muriatic acid gas will be liberated, and will be absorbed by the water of the first bottle, till this has become saturated. It will then pass on to the second bottle, and be there absorbed. The water employed may amount to half the weight of the salt, and may be equally distributed between the two bottles. These it is better to surround with cold water, or, still preferably, with ice or snow; because the condensation of the gas evolves considerable heat, which prevents the water from attaining its full impregnation. When the whole of the sulphuric acid has been added, and the gas no longer issues, let a fire be lighted in the furnace, beneath the sand-bath, removing the bent tube *a*, and substituting a well-ground glass stopper. This will renew the production of gas; and the temperature must be preserved, as long as gas continues to be evolved. At this period it is necessary to keep the luting, which connects the retort and receiver, perfectly cool; otherwise it will be apt to melt. To this juncture, indeed, I prefer the application of the clay and sand lute; but this requires some address. Towards the close of the process, a dark-coloured liquid is condensed in the first receiver, consisting of a mixture of sulphuric and muriatic acids. When nothing more comes over, the operation may be suspended, and the liquid in the two bottles must be preserved in bottles with ground stoppers. It consists of liquid muriatic acid.

The liquid muriatic acid may also be obtained by diluting the sulphuric acid with the water necessary for the condensation of the gas, and adding the dilute acid, when cold, to the salt in the retort. To the retort, an adopter may be luted with the clay and sand lute; and this may terminate in a large tubulated receiver, from the aperture of which a right-angled Welter's tube proceeds, and is conveyed beneath a few ounces of water, contained in a two-necked bottle. A fire must then be lighted under the sand-bath, and continued as long as any liquid comes over. The adopter and receiver must be kept cool, by the constant application of moistened cloths.

The acid formed in this mode has the specific gravity only of about 1170; but by the preceding process, and especially when the bottles are surrounded by ice or snow, it approaches that of 1500. It possesses the following characters:

1. It emits white suffocating fumes. These consist of muriatic acid gas, which becomes visible by contact with the moisture of the air.

2. When heated in a retort, or gas-bottle, muriatic acid gas is disengaged, and may be collected over mercury.

3. Liquid muriatic acid is not decomposed by the contact of charcoal, essential oils, or other combustible bodies.

4. When diluted with water, no remarkable elevation of temperature is produced.

5. In a perfectly pure state it is quite colourless; but it has frequently a yellowish hue. This may proceed, either from a portion of oxygenized muriatic acid, or of muriate of iron, but, I believe, most commonly of the latter. This colour is instantly destroyed by a few drops of muriate of tin.

6. Muriatic acid combines readily with alkalies, and with most of the earths, both in their pure and carbonated states.

SECTION II.

Muriates.

ART. I.—*Muriate of Potash.*

Muriate of potash may be obtained by saturating muriatic acid with carbonate of potash, and evaporating the solution till the salt crystallizes. These crystals have a cubical shape, and a bitter, disagreeable taste; they dissolve in three times their weight of water, at 60°, and in a rather less proportion of boiling water. They undergo little change when exposed to the air; they decrepitate when thrown on the fire, but abandon only a small portion of their acid.

ART. II.—*Muriate of Soda.*

Muriate of soda is that well known substance, common salt, which is become a necessary ingredient in the food of man, and is of essential utility in several of the arts.

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

But for purposes of experiment, the common salt may be employed, which is to be found in the shops. This may be purified, by adding to a solution of it in water a solution of carbonate of soda, as long as any milkiness ensues; filtering the solution, and evaporating it till it crystallizes.

II. Its qualities are as follow:

1. It crystallizes in regular cubes, which, when the salt is pure, are but little changed by exposure to the air. The common salt of the shops, however, acquires an increase of weight, in consequence of the absorption of moisture. The various forms under which it appears, of stoved salt, fishery salt, bay salt, &c. arise

rather from differences in the size and compactness of the grain, than from any essential difference of chemical composition.

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

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

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

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

6. When mixed with powdered charcoal or sulphur, and fused in a crucible, it does not undergo any decomposition or essential change; because the muriatic acid, if it contain any oxygen (which has not yet been proved), holds that basis more strongly combined than it is attracted by combustible bodies.

7. It is decomposed by the carbonate of potash, the alkali of which combines with the muriatic acid of the salt, and the carbonic acid is transferred to the soda.—Hence we obtain muriate of potash and carbonate of soda. A process for effecting this decomposition, on a large scale, is described by Westrumb, in Crell's Journal, English translation, ii. 127.

8. It is decomposed by the sulphuric acid in the mode already described. Nitric acid also separates the muriatic acid.

ACT. III.—*Muriate of Ammonia.* [See Note 25.]

1. If equal measures of ammoniacal gas and muriatic acid gas be mixed together, over mercury, they are immediately condensed, a white cloud is formed, and a solid substance is deposited on the sides of the vessel.—This is the muriate of ammonia.

For the purposes of experiment, it may be procured in the shops, under the name of sal-ammoniac.

Its properties are as follow:

(*a.*) It is volatilized, without being liquefied or 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. In boiling water it is still more soluble; and the solution, on cooling, shoots into regular crystals.

(*c.*) It slightly attracts moisture from the air.

(*d.*) On the addition of a solution of pure potash, or pure soda, the alkali is disengaged, as is evinced by the pungent smell that arises on the mixture of these two bodies, though perfectly inodorous when separate.

(*e.*) It is also decomposed by barytes, strontites, lime, and magnesia.

For the purpose of separating the volatile alkali, and obtaining it in a liquid form, lime is generally employed. Two parts of powdered and sifted lime are to be mixed with one of muriate of ammonia, and put into a retort, the neck of which is to be luted (with slips of moistened bladder, bound down by string), to a tubulated receiver, (fig. 31. *a*). From the other opening of the receiver, a right-angled tube, with Welter's addition (fig. 31. *b*), is to proceed, and to terminate beneath the surface of water, contained in a two-necked bottle (*c*). This bottle is to be connected, by a second right-angled tube, with another similar bottle (*d*), containing (as should the first also) a quantity of water, equal in weight to one-fourth that of the muriate of ammonia. The decomposition is effected by heat; and the gas is absorbed by the water contained in the bottles, which should be surrounded by ice or snow. The water acquires a strong smell, and has its specific gravity diminished, when fully impregnated, to 0.9684. This watery solution, when heated in a gas-bottle, gives up its ammonia, which passes over in an aeriform state, and may be received over quicksilver.

A solution of ammonia, in water, may also be obtained, as follows: Slack two parts of quicklime, with two of water; add to this, when cold, one part of muriate of ammonia, and six parts of water. Stir the mixture, and transfer it into a retort; lute on a receiver; and separate, by distillation, one part of liquid. The former process, however, is incomparably the best.

When a mixture of one part of powdered muriate of ammonia with two of powdered carbonate of lime (chalk), both perfectly free from moisture, is distilled together in a retort, a solid white substance condenses on the inner surface of the receiver. This is the carbonate of ammonia; and the process now described is that by which, with the substitution of proper subliming vessels, the carbonate of ammonia is prepared for sale. This operation furnishes an example of double affinity. The carbonic acid, being transferred from the lime to the ammonia, forms carbonate of ammonia; and the muriatic acid, passing to the lime, composes muriate of lime.

Art. iv.—*Muriate of Barytes*

Is best prepared, by dissolving either the artificial or native carbonate in muriatic acid much diluted; or, if neither of these can be had, the sulphuret. The iron and lead, which are occasionally dissolved, along with the barytes, may be separated by the addition of a small quantity of liquid ammonia, or by boiling and stirring the solution in contact with a little lime. When filtered and evaporated, the solution yields regular crystals, which have most commonly the shape of tables, bevelled at the edges, or of eight-sided pyramids, applied base to base. They dissolve in five parts of water, at 60°, or in a still smaller quantity of boiling water; and also in alcohol. They are not altered by exposure to the atmosphere; nor are they decomposed, except partially, by a high temperature. The sulphuric acid separates the muriatic; and the salt is also decomposed by alkaline carbonates and sulphates.

Art. v.—*Muriate of Strontites.*

May be obtained by following the same process as that employed in preparing the barytic salt. The solution affords long slender hexagonal prisms, which are soluble in two parts of water, at 60°; and to almost any amount in boiling water. In a very moist atmosphere they deliquiate. They dissolve in alcohol, and give a blood-red colour to its flame.

Art. vi.—*Muriate of Lime.*

This salt may be prepared by dissolving carbonate of lime in muriatic acid, or by washing off the soluble part of the mass, which remains after the distillation of the solution of pure ammonia from muriate of ammonia and lime.

The solution crystallizes in six-sided striated prisms, terminated by very sharp pyramids. If it be evaporated to the consistence of a sirup, and exposed in a temperature of 32°, it forms a compact mass, composed of bundles of needle-shaped crystals, crossing each other confusedly.

The crystals dissolve in half their weight of cold water, and to an unlimited extent in boiling water, being, in fact, soluble in their water of crystallization.—They deliquiate rapidly in the air, and enter into fusion when heated. If fused in a crucible, and treated in the same manner as the nitrate of lime, they yield a solar phosphorus, called, from its discoverer, *Homberg's phos-*

phorus. When mingled with snow, they produce intense cold, as has already been described.

ART. VII.—*Muriate of Magnesia.*

This is also a deliquescent and difficultly crystallized salt. It has an intensely bitter taste; is soluble in its own weight of water, or in five parts of alcohol. Unlike the preceding minerals, it is decomposed by ignition in a high temperature.

The muriates of magnesia and lime are generally contained in muriate of soda, and impart to that salt much of its deliquescent property. They impair, too, its power of preserving food. They are also ingredients of sea-water.

ART. VIII.—*Muriate of Alumine*

May be formed by dissolving fresh precipitated alumine in muriatic acid; but the acid is always in excess. It is scarcely possible to obtain this salt in crystals; for, by evaporation, it assumes the state of a thick jelly. It is extremely soluble in water, and deliquescent when dry. In a high temperature it abandons its acid entirely.

ART. IX.—*Muriate of Glucine.*

This salt is little known. Like all the salts of glucine, it has a sweet taste, and crystallizes more readily than the nitrate.

ART. X.—*Muriate of Zircon.*

Fresh precipitated zircon is readily dissolved by muriatic acid. The compound is colourless; has an astringent taste; and furnishes, by evaporation, small needle-shaped crystals, which lose their transparency in the air. It is very soluble in water and in alcohol. It is decomposed by heat, and by the saliva of the mouth. The gallic acid, poured into the solution, precipitates, if it be free from iron, a white powder. Carbonate of ammonia gives a precipitate, which is re-dissolved by an excess of the carbonate.

ART. XI.—*Muriate of Yttria.*

This compound has a striking resemblance to nitrate of yttria. Like that salt it dries with difficulty, and attracts moisture from the air. It does not crystallize, when evaporated, but forms a jelly.

CHAPTER XIV.

OXYGENIZED MURIATIC ACID, AND ITS COMPOUNDS.

SECTION I.

Oxygenized Muriatic Acid.

I. This acid may be formed by either of the following processes; which do not, however, afford a gas of precisely the same composition. That obtained by the third method is best adapted for exhibiting its effects on combustible substances.

Process 1. 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.

Process 2. 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 1. As the gas is absorbed by contact with water, though not rapidly, it should be received, when it is intended to be kept, in bottles filled with, and inverted in, water, and provided with ground stoppers. The stoppers must be introduced under water, while the bottle remains inverted.

Process 3. To an ounce-measure of liquid muriatic acid, contained in a gas-bottle, add three or four drachms of a salt, which will presently be described, the hyper-oxygenized muriate of potash. If the acid be very concentrated, gas will be evolved without the application of heat; and, when it has ceased to be generated, the production will be renewed by a gentle heat, such as that obtained by immersing the gas-bottle in a vessel of warm water. Receive the gas into bottles, furnished with extremely well ground stoppers; and, when they are full, put the stopper into its place, and invert the bottles, with their mouths downwards, in mercury.

As this gas is rapidly absorbed by cold water, the water of the receiving trough should be of the temperature of between 80° and 90° Fahrenheit; and the gas should remain, as short a time as possible before use, in contact with water. Mercury is not adapted for its reception, because on this metal the gas exerts a considerable action.

II. Oxygenized muriatic acid 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 gases.

When a receiver, filled with this gas, is surrounded by snow, or pounded ice, the gas forms on its surface a solid concretion, of a yellowish colour, resembling, in its ramifications, the ice which is deposited on the surface of windows during a frosty night. By a moderate increase of heat, such as to 50° Fahrenheit, this crust melts into a yellowish oily liquid, which, on a farther elevation of temperature, passes to the state of a gas.

(*d*.) The oxygenized muriatic acid exerts powerful effects on various combustible bodies, both aeriform, liquid, and solid.

1. Let a vial, provided with a well ground stopper, be filled with a mixture of hydrogen, and oxy-muriatic gas, procured by process 3, in the proportion of three of the former to four of the latter. Put the stopper into its place, and keep the bottle, 24 hours, inverted with its mouth under water. On withdrawing the stopper, nearly the whole of the gas will have disappeared: and the remainder will be absorbed by the contact of water. In this experiment, the oxygen of the acid gas combines with the hydrogen, and forms water; and the acid returns to the state of common muriatic acid.

2. Mingle, in the detonating tube (fig. 28 or 29.), three measures of hydrogen gas with four of oxygenized muriatic gas. When an electric spark is passed through the mixture, a detonation will ensue, and nearly the whole will be absorbed. The proportion of hydrogen and pure oxy-muriatic gases, required for mutual saturation, according to Mr. Cruickshank, is 3 of the former to 3½ of the latter.

3. Both the foregoing experiments may be repeated, with the substitution of carburetted hydrogen gas from moistened charcoal, from distilled coal, or from stagnant water. A larger proportion of the oxygenized acid, however, must be used, viz. three

or four measures to one of the combustible gas. In this case, also, the diminution is not complete; for there remains a quantity of carbonic acid gas, which may be absorbed by lime liquor. If a proportion of oxy-muriatic gas, less than what is required for saturation, be fired with any of these gases, there is an abundant precipitation of charcoal.

4. The carbonic oxide is converted, by contact with the oxy-muriatic gas, into carbonic acid. Mix 2 measures of the carbonic oxide with 2-3ds of the oxygenized gas; and allow them to stand, for 24 hours, in a bottle which is entirely filled by the mixture. On withdrawing the stopper at this period under water, the water will rush in, and will fill two-thirds of the bottle. The remaining one-third is carbonic acid gas, absorbable by lime water. It is remarkable, that a mixture of these two gases cannot be set on fire by the electric spark.

5. The olefiant gas exhibits, when mixed with oxy-muriatic gas, a very singular appearance. It is diminished in bulk, as rapidly as oxygen gas is by nitrous gas, and a thin film of oil forms on the surface of the water. The proportions required, for complete condensation, are 2½ measures of the olefiant to 3 of the oxygenized gas. This phenomenon is not perfectly understood.

6. Oxy-muriatic gas exerts no action on azotic gas; but nitrous gas is condensed by it, in the same manner as by oxygen gas.

7. When mixed with sulphuretted hydrogen gas, it occasions a condensation, and a precipitation of sulphur. It condenses sulphurous acid gas into sulphuric acid.

8. Phosphorus introduced into the oxygenized acid gas, takes fire spontaneously, and burns vehemently.

9. Sulphur is not inflamed by it; but a piece of sulphur fastened to the end of a glass rod, and confined in the gas, is slowly oxygenized, and drops down in a liquid form.

By passing streams of this gas through flowers of sulphur, Dr. Thomson obtained a new combination of oxide of sulphur with muriatic acid, which he terms sulphuretted muriatic acid—(Elements, 3d edit. i. 123.) An account of the properties of this substance may be seen as above, or in the sixth volume of Nicholson's Journal.

10. The charcoal of beech-wood, when finely powdered, and perfectly dry, is inflamed by this gas. So also is the pyrophorus of Homberg.

11. Almost every metal, in a state of minute division, takes fire spontaneously, and burns in this gas. The very malleable metals, such as gold, silver, &c. which can be reduced to extremely thin leaves, are best applied to the gas in this state. Others, as iron, zinc, copper, &c. must be introduced in the state of fine filings. The most readily oxydized metals burn with the greatest brilliancy. The proportion is about 40 grains of each metal to 40 cubic inches of gas; and, into the bottom of the receiver a little sand may be poured, to prevent it from being broken.

Metallic antimony burns with a very brilliant white flame, and throws out sparks. Arsenic exhibits a fine green or blue flame, attended with sparks, and a dense white smoke; bismuth, a blueish flame; nickel, a yellowish white one; cobalt, a blueish white; zinc, a white flame and sparks: tin, a blueish white light; lead, a clear white flame; copper, a red and slowly spreading light; and iron, a bright red light. In all these experiments, the temperature of the gas should not fall short of 70°; and, to ensure their success, it should be prepared by the third process.

(*e.*) 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.

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

The best method of effecting the impregnation of water with this gas, is by means of a Woulfe's apparatus, the bottles of which should be surrounded by ice-cold water. The precise bulk of the gas, which water is capable of absorbing, is not ascertained. According to the proportions stated by Berthollet, 1000 grains of water, at the temperature of 43° Fahrenheit, take up 1073 grains of the gas, and acquire the specific gravity of 1003.

(*g.*) The watery solution, if perfectly free from common muriatic acid, has not the usual taste of an acid, but an astringent one. Its purity from muriatic acid may be ascertained by a solution of nitrate of mercury, which is precipitated by the common, but not by the oxygenized-acid.

(*h.*) 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.

That its action in bleaching is attended with the decomposition of the acid, and the deprivation of its oxygen, may be ascertained by examining a portion of the liquid, by means of which several paterns of unbleached calico have been successively whitened. The liquor will be found almost entirely to have lost its smell, and to precipitate nitrate of mercury abundantly.

(*i*) 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.

(*k*.) The oxygenized acid is not decomposed by the temperature of boiling water; for it may be raised in distillation, and again condensed without change.

(*l*.) 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 oxygen gas may be collected, by exposing the solution in a gas-bottle furnished with a ground stopper and bent tube, which terminates in the pneumato-chemical apparatus.

(*m*.) The oxygenized muriatic acid combines with alkalis, and forms peculiar compounds.

SECTION II.

Hyper-oxygenized Muriates.

ART. I.—*Hyper-oxygenized Muriate of Potash.* [See Note 26.]

The properties of this salt were discovered by Berthollet. It may be formed by passing the oxygenized muriatic acid gas, as it proceeds from the mixture of muriate of soda, sulphuric acid, and manganese (see the preceding section, process 2) 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 alkaline 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 alkaline solution, was purely oxygenized muriatic acid, it follows that a part of this acid must have been dis-oxygenized 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 alkaline 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 alkali, forms muriate of potash.—The latter portion, therefore, is oxygenized acid, *plus* a certain quantity of oxygen; and this, uniting with another portion of alkali, 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. and also to Mr. Hoyle's Essay, in the 5th vol. of the Manchester Memoirs.

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 five parts of hot water take up two of the salt.

(*c*.) It is not decomposed by exposure to the direct rays of the sun, either in a crystallized or dissolved state.

(*d*.) When the hyper-oxygenized muriate is submitted to distillation in a coated glass retort, it first fuses, and, on a further increase of temperature, yields oxygen gas of great purity. A hundred grains of the salt afford 75 cubic inches of gas, containing only about three per cent. of azotic gas.

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

(*f*.) 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 concentrated sulphuric acid. A strong smell will arise, and, if the quantities be sufficiently large, an explosion will ensue. The experiment should, therefore, be attempted with great 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.)

Muriatic acid, as has already been stated, disengages the oxygenized acid; and the addition of a few grains of the salt to an ounce-measure of the acid, imparts to it the property of discharging vegetable colours.

(*g*) This salt exerts powerful effects on inflammable bodies.

1. 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.

2. 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.

3. 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.

4. 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. (Davy.) 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.

5. Hyper-oxygenized muriate may be substituted for nitre in the preparation of gunpowder, but the mixture of the ingredients requires extreme 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.

ART. II.—*Hyper-oxygenized Muriate of Soda.*

This salt may be obtained, by following the process already described, with the substitution of pure soda for potash. It is exceedingly difficult, however, to obtain it pure; because it nearly agrees, in solubility, with the common muriate of soda. It is soluble in three parts of cold water, and in rather less of hot, and is slightly deliquescent. It is soluble also in alcohol; but so also, according to Mr. Chenevix, is the common muriate. It crystallizes in cubes, or in rhomboids approaching the cube in form. In the mouth it produces a sensation of cold, and a taste scarcely to be discriminated from that of muriate of soda. In other properties it agrees with the similar salt with base of potash.

ART. III.—*Hyper-oxygenized Muriate of Ammonia.*

This salt cannot be procured by the direct union of the oxygenized acid with pure ammonia, because these two bodies mutually decompose each other; as will appear from the following experiments.

1. Fill a pint receiver with the oxygenized acid, prepared by the third process; and pour into it half a drachm of the strongest solution of ammonia that can be procured. A detonation will presently ensue.

2. Fill a four-ounce bottle with the oxygenized acid, and invert it in a cup containing 4 oz. measures of the solution of pure ammonia. Presently the liquor will be absorbed, and a detonation will ensue, which will throw down the bottle, unless firmly held by the hand. In the bottle there remains a portion of gas, which is azotic gas.

3. Pass the oxygenized acid through a solution of ammonia in a Woulfe's bottle; from one neck of which a tube proceeds, and terminates under the inverted funnel of the pneumatic trough. Bubbles of gas will be formed, and may be collected in an inverted receiver. They consist of pure azotic gas.

In all these experiments, the redundant oxygen of the acid unites with the hydrogen of the ammonia, and forms water, while the azote of the ammonia is liberated in a gaseous state. A combination of ammonia, with the hyper-oxygenized muriate may be formed, by adding a solution of carbonate of ammonia to one of hyper-oxymuriate of lime. A salt is obtained, on evaporation, which is very soluble in water and in alcohol, and which is decomposed at a moderate temperature, yielding a quantity of gas and a smell of oxymuriatic acid. Its properties have not been much investigated.

The property which ammonia possesses, of decomposing oxygenized muriatic acid, renders it extremely useful in correcting the offensive vapours of that 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 the oxygenized acid, the most effectual remedy is to hold a stopper, moistened with ammonia, to the mouth and nostrils.

ART. IV.—*Remaining Hyper-oxygenized Muriates.*

To effect the combination of barytes and strontites with the hyper-oxygenized acid, those bases must be dissolved in hot wawater, which must be kept hot while the current of gas is transmitted through the solution. Lime may also be combined with the oxygenized acid, and must, to this end, be kept suspended by mechanical means. This compound derives importance from its application to the art of bleaching; for it possesses, when perfectly saturated, bleaching properties; and in this state produces whiteness in the unbleached part of goods, without destroying any delicate colours which they may contain. The salt, with base of lime, is extremely deliquescent; liquefies at a low heat; and is soluble in alcohol. It produces much cold by solution, and a sharp taste in the mouth.

For an account of the remaining salts formed with this acid, Mr. Chenevix's paper may be consulted.

SECTION III.

Nitro-muriatic Acid.

This acid is a compound of the nitric and muriatic acids, 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.

The nitro-muriatic acid does not form, with alkaline, or other bases, a distinct genus of salts, entitled to the name of nitro-muriates; fo when combined with an alkali, or an earth, the solution yields, on evaporation, a mixture of a muriate and a nitrate; and metallic bodies, dissolved in it, yield muriates only. In the latter case, the nitric acid is decomposed, oxydizes the metal, and renders it soluble in muriatic acid.

CHAPTER XV.

PHOSPHORUS.....PHOSPHORIC ACID.....PHOSPHATES.

SECTION I.

Phosphorus.

I. Phosphorus is an inflammable substance, and is known by the following external 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.

II. 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.

1. 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.

2. In oxygen gas it burns with a very beautiful light; and also in nitrous oxide, and in oxygenized muriatic acid.

III. Phosphorus is volatile at 550°. 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 be immersed in water.

To accomplish this, the quantity of phosphorus, which it is intended to rectify, should first be put into the retort, with a sufficient portion of water to cover it. The water must then be made hot enough to melt the phosphorus, which, on cooling, forms a compact mass, of the shape of the bottom of the retort. When cold, fill the retort, and its neck also, with water, and invert it in water. Displace the water by hydrogen gas. forced from a bladder through a bent pipe; keep the finger on the open end of the retort neck; place it in a sand bath; and immerse the mouth of it in water. Then apply heat very cautiously. A bladder should also be provided, furnished with a stop-cock and brass pipe, and filled with hydrogen gas. During the distillation, the gas, 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. In the neck of the retort a substance is condensed of a beautiful red or carmine colour, which is a combination of carbon and phosphorus, or a *phosphuret of carbon.*

IV. 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.

A large quantity of acid may be obtained, if a number of sticks be thus exposed: and as they would be in danger of taking fire, if heaped together, each stick should be enclosed in a glass tube, of rather larger diameter than itself. These tubes must be disposed round a funnel, the pipe of which terminates in a bottle. The whole should be covered by a bell-shaped receiver, the air of which is to be frequently changed. The acid thus obtained is termed the *Phosphorous Acid.*

(*b.*) By combustion in oxygen gas, or in 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 cautiously added, by a little at once, to nitric acid, heated in a mattrass, the nitric acid is decomposed, and its oxygen, uniting with the phosphorus, constitutes phosphoric acid.

A tubulated retort must be used for this purpose; and its neck may terminate in the apparatus already described for procuring nitric acid. By this contrivance a considerable quantity of acid will be saved.

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* On the oxides of phosphorus, see Nich. Journ. vi. 133.

(*d.*) A similar effect is produced by oxygenized muriatic acid in a liquid state. The operation of this acid, in a gaseous form, has already been described.

Accordingly as the phosphoric acid is differently prepared, its degree of oxygenation differs, and its properties are found to vary proportionably.

The *phosphorus* acid exhales a disagreeable and fetid odour; and, when heated, yields penetrating white vapours. When heated in a glass ball, blown at the end of a small tube, a gas issues from the orifice of the tube, which takes fire on coming into contact with the atmosphere. Hence it appears to contain an excess of phosphorus. The residuum, after being thus heated, is phosphoric acid.

SECTION II.

Phosphoric Acid.

I. To prepare this acid, the process *b*, *c*, or *d*, sect. 1. may be employed; but the following is the most economical method.

On 20 pounds of bone, 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 let it be washed 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.—According to Fourcroy and Vauquelin, it is, in fact, a superphosphate of lime, containing, in 100 parts, only 30 of uncombined phosphoric acid, and 70 of neutral phosphate of lime.

To procure the phosphoric acid perfectly pure, the oxygenation 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.

II. 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, nor does it emit any smell when heated.

(*c.*) When distilled in a earthern 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.

The phosphoric acid may either be employed for this purpose in the state of glass, finely powdered, and mixed with its weight of pulverized charcoal; or to the evaporated acid of bones, when acquiring a thick consistence, powdered charcoal may be added, in sufficient quantity, to give it solidity. In the latter mode, however, the materials are apt to swell, and to boil over. The mixture of acid and charcoal is then to be put into a stoneware retort, coated with Willis's lute, and the neck of which is lengthened out by a tin pipe. The open end of the pipe is to be immersed in a vessel of water. The heat is to be slowly raised, and at length made very intense. An enormous quantity of gas escapes, which takes fire on coming into contact with the atmosphere; and the phosphorus distils over in drops, which congeal in the water. As it is apt also to condense in, and to stop up, the neck of the retort and tin-pipe, it must be occasionally melted out of these, by a shovel full of hot cinders, held under them. The process is rather a difficult one; and though it is proper that the student should repeat it once, in order to complete a course of experiments, it will be found more economical to purchase, from the London preparers, the phosphorus which may be required for experiments.

Phosphorus may also be procured, by adding to urine a solution of lead in nitric acid, which precipitates a phosphate of lead. This, when well washed, dried, and distilled in a stoneware retort, yields phosphorus (see Crell's Journal, Transl. iii. 36.): or a solution of phosphate of soda (which may be bought at the druggists), mixed with one of acetite of lead, in the proportion of one part of the former salt to 1¼ of the latter, yields a precipitate of phosphate of lead, from which phosphorus may be procured by distillation.

SECTION III.

Phosphates.

With alkaline and earthy bases, the phosphoric acid composes a class of salts called Phosphates, which have the following generic characters.

1. When heated with charcoal, they are not decomposed, nor is phosphorus obtained.

2. They melt, before the blow-pipe, into a hard globule, sometimes transparent, at others opake.

3. They are soluble in nitric and muriatic acids, without effervescence, and are precipitated from those acids by lime-water and pure ammonia.

4. They are decomposed, in part, by sulphuric acid, and yield a liquor which, on evaporation and distillation with charcoal, affords phosphorus.

The phosphate of soda is the only one of these salts which has any important use. It has been introduced into medicine, by Dr. Pearson, as a purgative, the purposes of which it answers, unaccompanied by any nauseous taste. The phosphate of lime, besides being found in the earth in a mineral form, constitutes a large part of the solid matter of animal bones.

As an enumeration of these salts can scarcely be interesting to the general student, and as the properties of the various salts, already described, furnish abundant discriminating characters of the different alkalies, and earths, I deem it sufficient to refer, for a detailed account of them, to Dr. Thomson's Elements, or La Grange's Manual.

SECTION IV.

Phosphites.

The phosphites differ considerably in their characters from phosphates.

1. They exhale a smell of phosphorus.

2. When heated, they emit a phosphorescent flame.

3. Distilled in a strong heat, they yield a little phosphorus, and are converted into phosphates.

4. They detonate, when heated with oxy-muriate of potash.

5. They are changed into phosphates by nitric, and by oxygenized muriatic acid.

SECTION V.

Binary Compounds of Phosphorus.

I. Phosphorus is susceptible of combination with sulphur, and affords a compound, the properties of which vary, according to the proportion of its ingredients. It may be obtained by melting these substances together in a tube, the mouth of which is loosely stopped by paper; or by fusing these two bodies, very cautiously, at the bottom of a Florence oil flask, nearly filled with water. The process is attended with some danger; and requires several precautions, which will be suggested by the essays of Accum and Briggs, published in the 6th and 7th volumes of Nicholson's Journal. The compound is much more fusible and combustible, than the separate components.

II. Phosphorus combines with the pure fixed alkalis, and with earths, and composes the class of phosphurets. That of lime is the most readily formed, and exhibits, extremely well, the properties of these compounds. It is prepared as follows:

Take a glass tube, about 12 inches long and 1-3d 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.

If the carbonate of lime be subsituted for pure lime, the carbonic acid is decomposed. Its carbon is set at liberty, and appears in the state of charcoal; while its oxygen unites with the phosphorus; and the phosphoric acid, thus produced, forms phosphate of lime. In this experiment, carbonic acid is decomposed by the conspiring affinities of phosphorus for oxygen, and of lime for phosphoric acid, though the former affinity only would be inadequate to produce the effect.

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 phosphuretted 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.)

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

ART. III.—*Phosphuretted Hydrogen Gas.*

I. 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 alkali, while the hydrogen dissolves another portion of phosphorus, constituting phosphuretted hydrogen gas.—This gas 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 take 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 alkaline solution*; otherwise the gas, when produced, will inflame and diminish the air within the retort, and the water will ascend from the trough. This ac-

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* The phosphorus should first be melted, under water, in the retort; which is to be emptied when the phosphorus has congealed, and then entirely filled by the alkaline solution. Of this, a sufficient portion is to be displaced by hydrogen gas, forced through a bent pipe from a bladder.

cident may be effectually prevented, by previously filling the retort with hydrogen gas.

II. 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. A circular dense white smoke rises in the form of a horizontal ring, which enlarges its diameter as it ascends, and forms a kind of corona.

(*b.*) When mixed suddenly with oxygen gas it detonates.

This experiment should be made cautiously, and in small quantity.

(*c.*) The same phenomenon ensues on mixing it with oxygenized muriatic acid gas, or with nitrous oxide.

When mingled with any of these gases, it should be passed up by not more than a bubble or two at once.

(*d.*) Sulphurous acid and phosphuretted hydrogen gases, when mingled together, mutually decompose each other.

(*e.*) It deposits phosphorus, by standing, on the inner surface of the receiver, and loses its property of spontaneous ascension.

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 oxygenized.—The simplest mode of making them is to put a little phosphorus, dried by blotting-paper, into a small vial; heat the vial, and when the phosphorus is melted, turn it round, so that the phosphorus may adhere to the sides. Cork the vial 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.

A correspondent in Nicholson's Journal (xi. 137.) proposes to effect the oxydation of phosphorus, by exposing 100 grains to half a pint of oxy-muriatic acid gas. The vessel must afterwards be well corked up. On applying a sulphur-match to the oxygenized phosphorus, it is inflamed, as in the foregoing example.

CHAPTER XVI.

BORACIC ACID. [See additions at the end.]

I. This acid is very rarely found native; and, for purposes of experiment, is obtained from the purified borax of commerce, by one of the following processes:

1. To a solution of borax, in boiling water, add half its weight of sulphuric acid, previously diluted with an equal quantity of water. Evaporate the solution a little; and, on cooling, shining scaly crystals will appear, which consist of boracic acid. Let them be well washed with distilled water, and dried on filtering paper.

2. Let any quantity of borax be put into a retort, with half its weight of sulphuric acid, and half its weight of water. Boracic acid may be obtained by distillation, and may be purified, by washing in water, &c. as before.

II. Boracic acid has the following qualities:

1. It has a solid form, is destitute of smell, and nearly so of taste.

2. It fuses, when heated, and loses its water of crystallization. If the heat be increased suddenly, before it has lost its water of crystallization, its sublimes; but, otherwise, it melts into a glass, which is permanent in the strongest fire.

3. It is soluble in twelve parts of cold water, and in three or four of boiling water.

4. This solution reddens vegetable blue colours, and effervesces with alkaline carbonates.

5. It is soluble in alcohol, and the solution burns with a beautiful green flame.

6. It combines with alkalis and earths; but the only important combination which it forms is with soda. This compound is found native in India, and is brought to this country, under the name of tincal, or brute borax, which, when purified, affords the borax of the shops. In the borate of soda, the alkaline ingredient is in excess, and hence the salt converts vegetable blue colours to green. It is therefore, in strictness, a sub-borate.

Sub-borate of soda crystallizes in prisms with six irregular sides. It effloresces in the air. It fuses when ignited; loses its water of crystallization; and leaves a glass, which is transparent when cold, and which is of great use in experiments with the blow-pipe. The salt dissolves in 12 parts of cold water, or in six of boiling water. It is susceptible of combination, by fusion, with silex and with alumine; and hence is employed in making artificial gems.

For a description of the remaining borates, I refer to the 2d vol. of Thompson's Elements, or the 1st vol. of La Grange's Manual.

CHAPTER XVII.

FLUORIC ACID. [See additions at the end.]

I. THE fluoric acid may be obtained from a substance found abundantly in Derbyshire, under the name of *fluor spar*. In converting this spar to ornamental purposes, small pieces are broken off, which may be had at a cheap rate.

The fluoric acid may be separated from this combination, *in the form of gas*, by adding, to the powdered spar, in a block tin or leaden gas-bottle, half its weight of concentrated sulphuric acid. The gas, which is disengaged, may be conducted, by a bent glass tube, to the mercurial trough. The receivers employed should be previously coated with wax, by making them hot enough in an oven to melt that substance, and then allowing the wax to run in fusion over their whole inner surface. This gas, in its properties, bears a considerable resemblance to muriatic acid gas. It has somewhat of a similar smell; produces a white smoke in the atmosphere; and is rapidly absorbed by water and by ice. It has the remarkable property of corroding glass. This may be observed by passing up, into a jar filled with it, a small slip of glass, which will be considerably acted on; or by holding a piece of glass over a mixture of concentrated sulphuric acid, and powdered fluate of lime. If partially applied, by covering the glass with a cement of wax and resin, and removing the cement in part only, the gas may be employed for writing or engraving on glass; and its application to this purpose has been proposed as an important improvement in the art of engraving, by Professor Wilson of Glasgow. (Nich. Journ. 4to. ii. 60.)

The fluoric acid may also be obtained *in a liquid state*, by using a leaden retort and leaden receiver. An ingenious apparatus, invented for this purpose by Mr. Knight, is described and figured in the 17th vol. of the Philosophical Magazine.

The liquid acid must be preserved in leaden bottles, as it soon corrodes and penetrates glass ones. In this state of watery solution, it readily combines with alkalies, and forms soluble compounds. Its combinations with the earths are for the most part highly insoluble. The fluates have no properties that can render them interesting to the student, except the use of the alkaline ones as tests, which will be described in a subsequent part of the work.

CHAPTER XVIII.

OF METALS.

SECTION I.

Of Metals in General.

I. The metals are distinguished by the following characters: They are perfectly opake; have a kind of lustre peculiar to themselves; are insoluble in water; are fusible; have a specific gravity superior to that of any other simple body, none of them being less than six times heavier than water; and are all conductors of electricity. In the present state of science, they are simple bodies, or have not been reduced into more elementary principles. Some of them have the property of being extended under the hammer, or are *malleable;* and many of them may be drawn into wire, or are *ductile.* Other metals have neither of these properties. [See additions at the end.]

II. The metals at present known amount to 28; viz. 1. Gold; 2. Platina; 3. Silver; 4. Mercury; 5. Rhodium; 6. Palladium; 7. Iridium; 8. Osmium; 9. Copper; 10. Iron; 11. Nickel; 12. Tin; 13. Lead; 14. Zinc; 15. Bismuth; 16. Antimony; 17. Tellurium; 18. Arsenic; 19. Cobalt; 20. Manganese; 21. Chrome; 22. Molybdena; 23. Uranium; 24. Tungsten; 25. Titanium; 26. Columbium; 27. Tantalium; 28. Cerium.

III. The most important property, common to the whole class of metals, is their susceptibility of union with oxygen. The phenomena and results, however, of the oxydizement of different metals vary considerably.

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

2. Other metals undergo this change 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 oxides of different colours. In some instances, this process is accompanied by so copious an extrication of light and heat, as to exhibit a true combustion or inflammation. Arsenic and zinc, for example, burn in a high temperature with a brilliant flame. Copper, lead, and various other metals, are slowly oxydized under similar circumstances, and without any appearance of combustion.

3. Other metals are not oxydized, even by the combined operation of air and of an increased temperature; such are gold and platina. By a powerful discharge through them, from an electrical or galvanic battery, these metals have their affinity of aggregation so far overcome, as to combine readily with oxygen. Thus a wire of gold, silver, or platina, is volatilized by the discharge of an electrical battery: and the metal, in this state, is oxydized by the air of the atmosphere. The same metals also, and various others, beat into very thin leaves, burn with great brilliancy, and with differently coloured flames, by transmitting through them the discharge from a powerful galvanic combination.

4. All metals, that are oxydized by the combined operation of heat and atmospherical air, undergo the same change, much more speedily and remarkably in oxygen gas. Iron wire, when heated to ignition in the air, is slowly oxydized; but in oxygen gas, it burns with considerable splendour.

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

6. 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.

7. Metals, that do not attract oxygen, either from atmospherical air, from oxygen gas, or from water, are still capable of separating that principle from certain of the acids; and the easily oxydizable metals effect the same decomposition of acids with much greater facility. In thus communicating oxygen to the metals, those acids are the most efficient, in which the oxygen is retained only by a feeble affinity. For example, concentrated

sulphuric acid, at the temperature of the atmosphere, scarcely acts on any one of the metals; because the sulphur, which constitutes its base, strongly attracts and retains the acidifying principle. Muriatic acid, in a gaseous state, is still more inert; for it is incapable of imparting, and indeed has not been proved to contain, oxygen. On the other hand, nitric, nitro-muriatic, and oxygenized muriatic acids, readily abandon part of their oxygen, and act on metals with considerable energy. The dilution of sulphuric and muriatic acids with water, also, renders them capable of oxydizing metals; for, in this case water, is decomposed, as is evinced by the escape of hydrogen gas.

8. The oxydizement of a metal always precedes its solution; and no one metal is capable of uniting, when in a perfectly metallic state, with any acid. It must either be oxydized by the acid, or brought into contact with the acid already combined with oxygen. Hence the oxides of certain metals dissolve readily in some acids, which do not at all act on the respective metals themselves. Gold, for instance, is unchanged by muriatic acid; but with this acid its oxide easily unites.

9. The phenomena of the solution of a metal, and those attending the solution of its oxide, are essentially different. For the most part, the action of an acid on a metal is accompanied with the appearance termed effervescence, which always arises from the escape of a gas. Thus, when nitric acid acts on iron, the metal acquires oxygen at the expense of the acid, which is thus changed into nitrous gas. The same metal, added to diluted sulphuric acid, decomposes water; and an effervescence is produced by the escaping hydrogen gas. But the oxides of metals dissolve silently, and without effervescence; as may be seen by adding the red oxide of iron to nitric or sulphuric acid. In this case, the metal, being already combined with oxygen, has no tendency to decompose the acids.

10. The same metal is capable of uniting with various quantities of oxygen; and its oxides differ, both in external and chemical characters, according to their degree of oxydizement. Thus iron, combined with 28 per cent. of oxygen, gives a black oxide, with 48, a red one. Manganese, united with one-fifth of oxygen, affords a white oxide; with one-fourth, a red-one; and with two-fifths, one of a deep black colour. The larger the proportion of oxygen in these compounds, the more feeble the affinity by which it is retained. The black oxide of manganese, for example, submitted alone to the action of a high temperature,

readily abandons 10 or 12 per cent. of the 40 parts of oxygen with which the metal is combined; but no degree of heat is capable of separating the last 25 or 20.

11. The various oxides of the same metal form, with a given acid, very different compounds. Iron, for example, oxydized to the extent of only 27 per cent. affords, with sulphuric, nitric, or muriatic acid, a green salt, insoluble in alcohol, and precipitated at first of a white colour by prussiate of potash. Still further oxydized, or to the extent of 48 per cent. the same metal forms a reddish salt, which is soluble in alcohol, and precipitated by prussiate of potash of a deep blue colour.

12. Metals retain oxygen with different degrees of force. Some oxides (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 retains it. Thus, to reduce the oxide of iron, charcoal must be added.

The gradation in the affinities of metals for oxygen, is evinced also by the property which metals possess, of abstracting oxygen, under certain circumstances, from each other. Thus when the oxide of mercury is exposed to heat, in contact with iron-filings, the iron becomes oxydized, and the mercury re-appears in a metallic state. On the same principle, when glass, which contains oxide of lead, is fused along with metallic iron, the latter metal attracts oxygen from the former, and the lead is again metallized. This separation of oxygen from a metallic oxide, either by the simple action of heat, or of another combustible body, is termed the *revival* or *reduction* of a metal.

13. From their solutions in acids, metals are precipitated by alkalies in the state of oxides; and by other metals capable of producing this effect, in a metallic form. Thus, if to a solution of sulphate of copper, pure potash be added, a blue oxide is precipitated. But immerse a polished piece of iron in the same solution, and the copper will be separated in a metallic form, covering the iron with a coat of copper. In this instance, the affinity of iron for oxygen is superior to that of copper; and the latter metal, being de-oxydized, is no longer soluble in sulphuric acid.

14. Some of the metals are susceptible, by union with oxygen, of affording both oxides and an acid; or, in other words, are acidifiable. Such are chrome, arsenic, molybdena, tungsten, and columbium. These acids are capable of uniting with alkalis,

earths, and in many instances with metallic oxides, and of forming neutral salts.

IV. On a comparison of the resemblances among metals, both in physical and in chemical properties, various arrangements of these bodies have been founded. They were formerly divided into *noble* or *perfect*, and *base* metals. The *noble* metals are not oxydixed by exposure to the combined action of heat and air; and their oxides, when obtained by circuitous processes, or found native, abandon their oxygen, when heated alone, without the addition of any combustible matter. Under this description, are included gold, platina, silver, palladium, and, according to Richter's late experiments, nickel. Mercury, though oxydized by heat and air, has still been always comprehended under the same order; because its oxides are revived when heated *per se*. All the remaining metals fall under the denomination of *base* metals.

Another arrangement of metals is that which divides them into metals or *entire metals*, and *semi-metals;* and the principle of this arrangement is their possessing or not the quality of malleability. The *malleable* or *entire* metals, are gold, silver, platina, palladium, mercury (when frozen), iron, lead, zinc, copper, tin, and nickel*. The *semi-metals* are, bismuth, antimony, arsenic, manganese, cobalt, molybdena, and all that follow it in the preceding enumeration. Of these, however, several have been hitherto procured in such small quantity, that their properties still remain to be examined.

A third classification is that of Fourcroy, who divides the metals into five orders. 1. The *brittle and acidifiable* includes four species, viz. arsenic, tungsten, molybdena, and chrome. 2. The *brittle and simply oxydizable* are seven; titanium, uranium, cobalt, nickel (since shown by Richter not to belong to this division), manganese, bismuth, antimony, and tellurium. 3. The metals that are *oxydizable and imperfectly ductile*, are mercury and zinc. 4. The *ductile and easily oxydizable*, tin, lead, iron, and copper. 5. The *very ductile, and difficult* of *oxydizement*, are silver, gold, and platina.

The most recent arrangement is that of Dr. Thomson in the third edition of his System of Chemistry, and this classification I shall adopt; as it appears to me to be the best that has been contrived. He divides the metals into four classes. The 1st class comprehends the MALLEABLE METALS, which are 14 in num-

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* Per Richter.

ber; viz. gold, platina, silver, mercury, palladium, rhodium, iridium, osmium, copper, iron, nickel, tin, lead, and zinc. The second class includes the BRITTLE AND EASILY FUSED; viz. bismuth, antimony, tellurium, and arsenic. The third, metals that are BRITTLE AND DIFFICULTLY FUSED. These are cobalt, manganese, chrome, molybdena, uranium, and tungsten. The fourth class are termed REFRACTORY METALS, because they have never yet been exhibited in a separate form, but always in combination with oxygen. These are titanium, columbium, tantalium, and cerium.

V. Sulphur, and some of its combinations, are capable of uniting with metals and their oxides.

1. All the metals, excepting gold, and perhaps titanium, may be combined with sulphur. Of the remainder, iron and copper unite with sulphur in two very different proportions; in the one forming a *sulphuret;* and, in the other, a *super-sulphuret.*

2. Three of the metals, when oxydized, are capable of uniting with sulphur, viz. tin, zinc, and manganese. These compounds are termed *sulphuretted oxides.*

3. Several of the metallic oxides are susceptible of combination with sulphuretted hydrogen; and compose *hydro-sulphuretted oxides.* These are produced, when a metallic oxide is precipitated from its solution by the hydro-sulphuret of ammonia or of potash. It has not hitherto been ascertained, whether super-sulphuretted hydrogen can be united with metallic oxides; for the nature of the precipitates, separated from metallic solutions by hydroguretted sulphurets, has not been sufficiently investigated.

VI. The metals have an affinity for phosphorus, and combine with it, forming metallic *phosphurets.* The most effectual method of bringing about this combination, is to heat the metals in contact with phosphoric acid and charcoal. The charcoal deprives the acid of oxygen, and the phosphorus then unites with the metal. Those metals that are easily oxydized, decompose the acid, without the addition of charcoal. These compounds have not hitherto been applied to any useful purpose. They are fully described by Pelletier, in the 1st and 13th volumes of the *Annales de Chimie.*

VII. The compounds of metals with carbon are termed *carburets.* That of iron is the only one of which much is known.

VIII. The metals are for the most part capable of uniting with each other, and the compounds thus formed are termed *alloys.* Several of these have important practical uses.

IX. The metals are seldom found native, [See additions at the end,] and require generally to be separated by artificial processes, from the substances with which they are combined. For the most part, they occur in the state of oxides, and frequently in union with sulphur or arsenic. The volatile ingredients are separated by long exposure to a low red-heat, which is termed roasting; and they are deprived of oxygen by charcoal, or substances containing it, assisted by a strong heat. To enable the particles of reduced metal to approach each other, and cohere into a mass, substances are also mixed with the inflammable matter, which readily enter into fusion, and are termed *fluxes*. [See additions at the end.]

FIRST CLASS.

MALLEABLE METALS.

SECTION II.

Gold.

I. Gold may be melted by a moderate red-heat; and, when the heat is greatly increased, the metal is in part volatilized.

II. Pure gold is not oxydized by exposure to heat with the access of air.

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

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

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

VI It is decomposed by alkalies. A solution of pure ammonia separates an oxide of gold, and a portion of ammonia, uniting with the oxide, forms a compound which detonates very loudly in a gentle heat, and is termed *fulminating gold*.

To obtain this compound, add a solution of ammonia in water, or the pure liquid ammonia, to diluted muriate of gold; a precipitate will appear, which will be re-dissolved if too much alkali be used. Let the liquid be filtered, and wash the sediment, which remains on the filter, with several portions of warm water.

Dry it by exposure to the air, without any artificial heat, and preserve it in a bottle, closed, not with a glass-stopper, but merely by a cork. A small portion of this powder, less than a grain in weight, being placed on the point of a knife, and held over a lamp, detonates violently.

This detonation is explained as follows: Fulminating gold is composed of an oxide of that metal, combined with ammonia. When its temperature is raised, the ammonia is decomposed; the hydrogen of the alkali unites with the oxygen of the oxide, and reduces the gold to a metallic state; and azotic gas, and probably aqueous vapour, are liberated in a highly expanded state. The violent impulse of these aeriform products, on the surrounding atmosphere, appears to be the cause of the loud noise that is occasioned by the explosion of this compound. A similar explanation may be applied to other fulminating compounds of metallic oxides with ammonia; such as those of silver and mercury, which will be described hereafter.

VII. 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 also be so applied as to exhibit regular figures, when reduced.

(*c.*) The same experiment may be repeated, substituting phosphuretted 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.

VIII. Gold is precipitated from muriatic acid, in a metallic form, by a solution of green sulphate of iron.

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

IX. When a sheet of tin is immersed in a solution of nitro-muriate of gold, the oxide of gold is precipitated of a purple colour; and, when scraped off and collected, forms the purple powder of Cassius, much employed in enamelling. The same precipitate is obtained by mixing a solution of gold with a solution of tin in muriatic acid.

X. Gold is precipitated from its solvent by ether, but the oxide of gold is instantly re-dissolved by the ether, and forms the ethereal solution of gold.

XI. Sulphurets of alkalies 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.

XII. The methods of purifying gold, by the operations of cupelling and quartation, would lead into too long details. They are very perspicuously described by La Grange, in the 44th chapter of his *Manual*, and in Nicholson's *Principles of Chemistry*. To the former work, and to Dr. Thomson's *System*, vol. i. I refer also for information respecting the alloys of gold with other metals.

SECTION III.

Platina.

I. Platina, in the state in which it reaches this country, is contaminated by the presence of several other metals; and, in fact, is merely an ore of platina. It is in the form of small grains or scales, of a whiter colour than iron, and extremely heavy. Various processes have been contrived for its purification (see La Grange, vol. ii.); but the one, which is the most simple and practicable, appears to me to be that of Count Moussin Poushkin, communicated by Mr. Hatchett in the 9th volume of Nicholson's Journal. It is unnecessary, however, to detail these processes; as the metal may now be had, in a pure state, at a reasonable price; among other places, at Cary's, No. 182, Strand, London.

II. Platina has the following properties:

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

2. It is extremely difficult of fusion. It may be melted, however, by the blow-pipe, with the aid of oxygen gas.

3. It is not oxydized by the long-continued and concurrent action of heat and air.

4. It has the property of *welding**, which belongs to no other metal but this and iron.

5. It is not acted on by any other acid than the nitro-muriatic and oxygenized muriatic. The former is best adapted to effect this solution. Sixteen parts of the compound acid are to be poured on one of the laminated metal, and exposed to heat in a glass vessel; nitrous gas is disengaged, and a reddish-coloured solution is obtained, which gives a brown stain to the skin.

6. The muriate of platina may be crystallized by careful evaporation. The salt has a very acrid taste, and is deliquescent. It is decomposed by heat, and an oxide of platina remains, which is reduced to a metallic form by ignition with charcoal.

7. The muriate of platina has the characteristic property of being precipitated by a solution of muriate of ammonia. By this character, platina is distinguished from all other metals, and may be separated when mingled with them in solution. The precipitate, thus obtained, is decomposed by a strong heat, and leaves pure platina.

8. Muriate of platina is not precipitated by prussiate of potash, nor by sulphate of iron. If any precipitate ensue, it is owing to contamination with other metals.

9. It is precipitated of a dark green colour by the gallic acid as present in tincture of galls. The precipitate becomes gradually paler by standing.—La Grange, ii. 272.

10. When pure potash is poured into the muriatic solution, a precipitate ensues, which is not an oxide of platina, but a triple compound of that oxide with the alkali and acid. With soda, also, it forms a triple combination. This is best obtained, by adding to nitric acid, in a retort, platina, with twice its weight of muriate of soda, and applying heat till about four-fifths of the fluid have come over. The remaining liquor forms, on cooling, fine prismatic crystals, sometimes four or five inches long; and either reddish-brown, like titanium; yellow, like amber; or of a beautiful coquelicot colour.—Nich. Journ. ix. 8vo. 67.

11. Muriate of platina is precipitated by sulphuretted hydrogen.

12. Platina is acted upon by fusion with nitrate of potash, and also with pure fixed alkalis.

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* Two pieces of wrought iron, raised to a white heat, become covered with a kind of varnish; and, when brought into contact, may be permanently united by forging. This is called the welding of iron.

13. The most delicate test of the presence of platina is muriate of tin. A solution of platina, so dilute as to be scarcely distinguishable from water, assumes a bright red colour, on the addition of a single drop of the recent solution of tin.

14. Platina has been discovered by Dr. Wollaston to be a remarkably slow conductor of caloric. When equal pieces of silver, copper, and platina, were covered with wax, and heated at one end, the wax was melted $3\frac{1}{4}$ inches on the silver; $2\frac{1}{2}$ on the copper; and 1 inch only on the platina. Its expansion by heat is considerably less than that of steel; which, between the temperatures of 32° and 212° is expanded about 12 parts in 10.000, while the expansion of platina is only about 10.

SECTION IV.

Silver.

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

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

III. Nitric acid diluted with, from 2 to 4 parts of water, dissolves it with a disengagement of nitrous gas. If the silver be pure the solution is colourless, otherwise it has a green hue. [See Note 27.] According to Proust, nitrate of silver already saturated, if boiled with powdered silver, dissolves an additional quantity; and a solution is obtained, in which the silver is oxydized only at a minimum. This nitrate, he observes, possesses different properties from the common one. (Nicholson, xv. 376.)

IV. 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. (See chap. iv. par. v.) If fused by a gentle heat, it forms a semi-transparent mass of the consistence of horn, called luna cornea, or horn silver.

Muriate of silver is decomposed by fusion with carbonate of soda. Mix one part of the former with three of the latter salt, and let the mixture be fused in a crucible. When cold, the silver will be found reduced at the bottom of the crucible; break the mass, and separate the metal. This is one of the best modes of obtaining silver in a state of purity.

V. 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.

White paper, or white leather, when stained with a solution of nitrate of silver, in the proportion of 10 water to one of the salt, undergoes no change in the dark; but when exposed to the light of day, it gradually acquires colour, and passes through a succession of changes to black. The common sun-beams, passing through red glass, have very little effect upon it; yellow and green are more efficacious; but blue and violet produce the most decidedly powerful effects. Hence this property furnishes a method of copying paintings on glass, and transferring them to leather or paper. The process is described by Mr. T. Wedgewood, in Nicholson's Journal, 8vo. iii. 167.

By a similar process, ivory may be covered with silver. Let a slip of ivory be immersed in a dilute solution of pure nitrate of silver, till the ivory has acquired a bright yellow colour. Then remove it into a tumbler filled with distilled water, and expose it to the direct light of the sun. After two or three hours exposure, it will have become black; but on rubbing it a little, the surface will be changed into a bright metallic one, resembling a slip of pure silver. As the solution penetrates deep into the ivory, the bright surface, when worn away, is replaced by a succession of others.

VI. 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.

VII. 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.* The most successful process for obtaining this appearance is given by Baumé. Mix together six parts of a solution of silver in nitric acid, and four of a solution of mercury in the same acid, both completely saturated. Add a small quantity of distilled water; and put the mixture into a conical glass, containing six parts of an amalgam made with seven parts of mercury and one of silver. At the end of some hours, there appears on the surface of the amalgam a precipitate in the form of a vegetation. According to Proust, this complicated process is quite unnecessary; and all that is required is to throw mercury into nitrate of silver very much diluted. A beautiful arborization of reduced silver, he observes, will be produced without fail.

VIII. The solution of silver is decomposed by charcoal, and by hydrogen gas and its compounds. This may be shown by experiments precisely similar to those already directed to be made with muriate of gold.

IX. 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.

X. A new detonating compound of silver, [See Note 28.] formed by a process similar to that employed in making the fulminating mercury of Mr. Howard, has lately been discovered by Descotils (Nich. Journ. xviii. 140.) It is prepared by adding alcohol, to a heated solution of silver in nitric acid, while the solution is yet going on. Considerable effervescence arises; the liquor presently becomes turbid; and a heavy, white, crystalline powder falls down. This, when washed and dried, is the *detonating silver*. Heat, a blow, or long continued friction, causes it to inflame with a brisk detonation. Pressure alone is not sufficient, unless very powerful. It detonates by the electric spark, and is set on fire with an explosion by concentrated sulphuric acid. Both in the preparation of this substance, and in experiments on its detonation, much caution is necessary; and only very small quantities should be employed.

XI. Silver is acted on by sulphurets of alkalies, and by sulphuretted hydrogen gas. Both these substances blacken silver when exposed to their operation; and the common tarnishing of silver by the atmosphere has been traced to a similar cause.

SECTION V.

Mercury.

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

II. When its temperature is reduced to about 40° below zero of Fahrenheit, it assumes a solid form. This is a degree of cold, however, that occurs only in high northern latitudes: and in this country quicksilver can only be exhibited in a solid state by means of artificial mixtures. By congelation it acquires an increase of its specific gravity; and therefore, unlike other metals, the congealed portion sinks to the bottom of a fluid mass of mercury. Its specific gravity, at 47° above 0 of Fahrenheit, being 13.545, it was found increased by congelation, in an experiment of Mr. Biddle, to 15.612, or about one-seventh.

III. At about 600° of Fahrenheit, mercury boils, and is changed into vapour. [See Note 29.] Hence it may be driven over by distillation, and may thus be purified, though not accurately, from the admixture of other metals. When its temperature is considerably increased above this point, the vapour acquires great expansive force, and the power of bursting the strongest vessels.

IV. Mercury is not oxydized, when pure, at the ordinary temperature of the atmosphere; but when boiled for a considerable time in a glass vessel, having a long narrow neck, it is converted into a reddish brown oxide. Long-continued agitation, however, in contact with the air, in a bottle half filled with the metal, converts a portion of it into a blackish oxide.

V. 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.

VI. Mercury is dissolved by nitric acid, [See Note 30.] 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 oxide, called red precipitate, which still contains a small portion of acid.

VII. Mercury is the basis of a new fulminating compound lately discovered by Mr. E. Howard. To prepare this powder,

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* Bergman's Essays, i. 133.

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 re-action. The precipitate is to be immediately collected on a filter, 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 re-action 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 fact, respecting the fulminating mercury, is stated by Mr. Accum. Four ounces of this substance were placed, still wet, on a chalkstone, 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.

VIII. 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, a combination of oxide of mercury and muriatic acid is obtained by sublimation. 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 oxide of murcury contains about 10 per cent. of oxygen, and the salt about 88 of the oxide, and 12 of muriatic acid. Corrosive sublimate, in 100 parts, has 82 of an oxide containing 15 per cent. of oxygen.—Chenevix, Phil. Trans. 1801.

IX. The oxides of mercury are all reduced by heat alone, without the addition of any combustible substance, and afford oxygen gas.

X. 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.

By combination with mercury, metals that are not easily oxydized, acquire a facility of entering into this union. Thus gold and silver, when combined with mercury, are oxydized by agitation in contact with air. This fact furnishes a striking illustration of the effect of overcoming the aggregative affinity of bodies in promoting chemical union.

XI. By combination with sulphur, mercury affords two distinct compounds. By long-continued trituration, these two bodies unite, and form a black sulphuret. When united together by fusion, and afterwards sublimed, they constitute a red sulphuret called cinnabar, which, when powdered, affords the common pigment vermillion. This compound also may be obtained by mixing concentrated solutions of muriate of mercury and hydrosulphuret of ammonia. A brownish muddy precipitate is obtained, which, when left undisturbed, turns yellow in three or four days, then orange, and finally acquires a beautiful cinnabar colour.—Accum, in Nich. Journ. 8vo. i. 299.

SECTION VI.

Rhodium and Palladium.

The discovery of these two metals we owe to the ingenuity of Dr. Wollaston, who separated them from the ore of platina, by the following process.

I. Rhodium. When a solution of the ore of platina in nitromuriatic acid has been precipitated, as far as possible, by muriate of ammonia (see sect. 3.), it still retains a considerable degree of colour, varying with the strength and proportion of the acids that have been employed in effecting the solution. Beside iron, and a portion of the ammonia-muriate of platina, it contains, also, other metals in very small proportion.

1. Let a cylinder, or thin plate of zinc, or iron, be immersed in the solution. It will separate all the metals that are present in the state of a black powder. Wash the precipitate (without drying it) with very dilute nitric acid, assisted by a gentle heat, which will dissolve the copper and lead. Digest the remainder in dilute nitro-muriatic acid; and to the solution,

when completed, add a portion of muriate of soda, equivalent in weight to about 1-50th the ore of platina employed Evaporate by a gentle heat. The dry mass contains the soda-muriates of platina, palladium and rhodium; the two former of which may be separated by alcohol, and the salt of rhodium will remain. From its solution, the rhodium may be precipitated by zinc, which throws down a black powder, amounting, in weight, to four grains from 4000 of the ore.

2. When exposed to heat, the powder continues black; with borax it acquires a white metallic lustre, but appears infusible by any degree of heat. It is rendered fusible, however, by arsenic, and also by sulphur; both of which may be expelled by a continued heat; but the metallic button, thus obtained, is not malleable.

3. The specific gravity of rhodium, as near as it could be taken, was 11.

4. Rhodium unites readily with all the metals that have been tried, except mercury. It does not discolour gold, when alloyed with it.

5. When an alloy of silver or gold with rhodium is digested in nitric or nitro-muriatic acid, the rhodium remains untouched; but when alloyed with three times its weight of bismuth, copper, or lead, each of these alloys may be dissolved completely, in a mixture, by measure, of two parts muriatic acid with one of nitric. The lead appears preferable, as it is reduced, by evaporation, to an insoluble muriate. The muriate of rhodium then exhibits the rose colour, from which the name of the metal has been derived. It is soluble in alcohol.

6. Rhodium is not precipitated from its solution by prussiate of potash, nor by muriate of ammonia, nor by hydro-sulphuret of ammonia. The carbonated alkalies produce no change; but the pure alkalies precipitate a yellow oxide, soluble in all acids that have been tried.

II. Palladium. 1. The alcoholic solution (I. 1.) contains the soda-muriates of palladium and platina. The latter metal may be precipitated by muriate of ammonia; and from the remaining liquid palladium may be obtained, by the addition of prussiate of potash, which occasions a sediment, at first of a deep orange colour, and changing afterwards to a dirty bottle-green, owing, probably, to the presence of iron. The precipitate is to be ignited, and purified from iron, by cupellation with borax.

2. A more simple method of obtaining palladium has since been announced by its discoverer*. To a solution of the ore of platina in nitro-muriatic acid, neutralized by evaporating the redundant acid, or by adding an alkali, and either before or after the separation of the platina by muriate of ammonia, let prussiate of mercury be added. In a short time the liquid becomes yellow, and a flocculent precipitate is gradually formed of a pale-yellowish white colour, which is the prussiate of palladium. This, on being heated, yields the metal in a pure state, in the proportion of 4-10ths or 5-10ths grain from every hundred grains of the ore.

Those who may wish to examine the properties of palladium, may now procure it in a metallic state at Messrs. Knights', Foster-lane, London.

3. The following are the properties of palladium.

(*a.*) Its colour resembles that of platina, except that it is of a duller white. It is malleable and ductile. Its specific gravity varies from 10.972 to 11.482. Its power of conducting caloric is nearly equal to that of platina, which it rather surpasses in expansion by heat.

(*b.*) Exposed in an open vessel, to a greater degree of heat than is required to melt gold, no oxydizement ensues; and no degree of fusion takes place. On increasing the fire considerably, a melted button is obtained, and the specific gravity is increased to 11.871. The metal, in this state, has a greyish-white colour. Its hardness exceeds that of wrought iron. By the file it acquires the brilliancy of platina; and is malleable to a great degree.

(*c.*) Palladium readily combines with sulphur. The compound is whiter than the separate metal, and is very brittle.

(*d.*) It unites with potash by fusion, and also with soda, but less remarkably. Ammonia, allowed to stand over it for some days, acquires a blueish tinge, and holds, in solution, a small portion of oxide of palladium.

(*e.*) Sulphuric acid, boiled with palladium, acquires a beautiful blue colour, and dissolves a portion of the metal. The action of this acid, however, is not powerful; and it cannot be considered as a fit solvent for palladium.

(*f.*) Nitric acid acts with much greater violence on palladium. It oxydizes the metal with somewhat more difficulty than silver;

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* Phil. Mag. xxii. 272, or Phil. Trans. 1805.

and, by dissolving the oxide, forms a very beautiful red solution. During this process no nitrous gas is disengaged. Nitrous acid has even a more rapid action on palladium.

(*g.*) Muriatic acid, by being boiled on palladium, acts upon it, and acquires a beautiful red colour.

(*h.*) But the true solvent of palladium is nitro-muriatic acid, which acts upon the metal with great violence, and yields a beautiful red solution.

(*i.*) From all these acid solutions of palladium, a precipitate may be produced by alkalies and earths. These precipitates are mostly of a fine orange colour; are partly dissolved by some of the alkalies; and that occasioned by ammonia, when thus re-dissolved, has a greenish-blue colour. Sulphate, nitrate, and muriate of potash, produce an orange precipitate in the salts of palladium, as in those of platina; but the precipitates from nitrate of palladium have generally a deeper shade of orange. All the metals, except gold, platina, and silver, cause very copious precipitates in solutions of palladium. Recent muriate of tin produces a dark-orange or brown precipitate, from neutralized salts of palladium, and is a very delicate test of this metal. Green sulphate of iron precipitates palladium in a metallic state; and, if the experiment succeed, the precipitate is about equal in weight to the palladium employed. Prussiate of potash causes an olive-coloured precipitate. The prussiate of palladium, separated by a neutral solution of prussiate of mercury, has the property, when heated to about 500° of Fahrenheit, of detonating, with a noise similar to that occasioned by firing an equal quantity of gunpowder. Hydro-sulphurets, and water impregnated with sulphuretted hydrogen gas, occasion a dark brown sediment from solutions of palladium.

(*k.*) Palladium readily combines with other metals. It has the property, in common with platina, of destroying the colour of gold, even when in a very small proportion.—Thus one part of platina, or palladium, fused with six of gold, reduces the colour of the gold nearly to that of the white metal employed.

SECTION VII.

Iridium and Osmium.

When the ore of platina has been submitted to the action of nitro-muriatic acid, a part remains undissolved, in the form of a black powder, resembling plumbago. In this substance, Mr.

Tennant has lately discovered two new metals. The process, which he employed to separate them was the following:

I. 1. The powder was fused in a silver crucible with pure soda, and the alkali then washed off with water. It had acquired a deep orange or brownish-yellow colour, but much of the powder was undissolved. The residue was digested in muriatic acid, and a dark-blue solution obtained, which afterwards became of a dusky olive-green; and, finally, by continuing the heat, of a deep-red colour. By the alternate action of the acid and alkali, the whole of the powder appeared capable of solution.

2. The alkaline solution contained the oxide of a volatile metal not yet described; and also a small portion of another metal. When the solution was kept some weeks, the latter metal separated spontaneously in thin dark-coloured flakes. The acid solution contained both metals also; but principally one, which is not altered by muriate of tin; is precipitated of a dark-brown colour by pure alkali; and which exhibits, during solution in muriatic acid, a striking variety of colours, arising from variations in its degree of oxygenizement.—From this property Mr. Tennant terms it Iridium.

3. In order to obtain muriate of iridium, free from the other metal, the acid solution (2) was evaporated, and an imperfectly crystallized mass obtained; but this, dried on blotting-paper, and again dissolved and evaporated, gave distinct octahedral crystals. The watery solution of these crystals had a deep-red colour, inclining to orange. With infusion of galls no precipitation ensued; but the colour almost instantly disappeared. Muriate of tin, carbonate of soda, and prussiate of potash, had the same effect. Pure ammonia precipitated the oxide, but retained a part, and acquired a purple colour. All the metals, except gold and platina, precipitated iridium of a dark colour from the muriate, which had lost its colour.

4. Iridium was obtained pure by heating the muriate, which expelled both the acid and the oxygen. It was of a white colour, and perfectly infusible. It did not combine with sulphur or arsenic. Lead united with it, but was separated by cupellation. Copper, silver, and gold, were severally found to combine with it, and it could not be separated from the two latter by cupellation with lead.—Its other properties remain to be examined.

II. 1. Osmium was procured in the state of an oxide, by simply distilling the alkaline solution, obtained as already described (I. 1.), along with any acid. It was even found to escape, in part, when water was added to the dry alkaline mass remaining in the crucible; and was manifested by a pungent and peculiar smell, from which property its name has been derived. The watery solution of oxide of osmium is without colour, having a sweetish taste, and the strong smell already alluded to. Another mode of obtaining, still more concentrated, the oxide of osmium, is by distilling the original black powder with nitre. A solution of oxide of osmium in water is found in the receiver, of such strength as to give a stain to the skin that cannot be effaced. The most striking test of this oxide is an infusion of galls, which presently becomes of a purple colour, and afterwards changes to a deep vivid blue. With pure ammonia, the solution becomes somewhat yellow; and slightly so with carbonate of soda. With alcohol, or still more quickly with ether, it acquires a dark colour, and, after some time, separates in the form of black films.

2. The oxide of osmium gives up its oxygen to all the metals, excepting gold and platina. When its solution in water is shaken with mercury, the solution loses its smell; and the metal, combining with the mercury, forms an amalgam. From this, much of the redundant mercury may be separated by squeezing it through leather, which retains the amalgam of a firmer consistence. The mercury being distilled off, the osmium remains in its metallic form, of a dark-grey or blue colour. By exposure to heat, with access of air, it evaporates with its usual smell; but, if oxydation be effectually prevented, it does not seem in any degree volatile. Being subjected to a strong white heat, in a cavity made in a piece of charcoal, it is not melted, nor does it undergo any change. With gold and silver it forms malleable alloys. These are easily dissolved in nitro-muriatic acid; and by distillation give the oxide of osmium with its usual properties.

3. The pure metallic osmium, which had been previously heated, does not seem to be acted upon by acids; at least no effect is produced by boiling it some time in nitro-muriatic acid. By heating it in a silver cup with alkali, it immediately combines with the alkali, and this compound gives, with water, a yellow solution, similar to that from which it had been procured. From this solution, acids expel the oxide of osmium, having its usual smell, and possessing the property of changing to a vivid blue the infusion of galls.

Besides the black powder from which osmium is obtained, Dr. Wollaston has discovered a separate ore of these two metals, mixed with the grains of crude platina. The specific gravity of this ore is about 19.5, and therefore exceeds that of crude platina itself, which is only 17.7. The grains are about the size of those of crude platina, but are considerably harder; are not at all malleable; and appear to consist of laminæ, possessing a peculiar lustre.

SECTION VIII.

Copper.

I. 1. Copper is oxydized 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.

A plate of copper, exposed for some time to heat, becomes covered with an oxide, which breaks off in scales when the copper is hammered. This oxide, when exposed on a muffle, is farther oxydized, and assumes a deep-red hue. Copper is also oxydized by long exposure to a humid atmosphere, and assumes a green colour; but the green oxide holds carbonic acid in combination. These compounds do not return to a metalic state by the mere application of heat; but require, for their reduction, the admixture of inflammable matter.

2. Copper does not decompose water, which may be transmitted, in vapour, through a red-hot tube of this metal, without decomposition.

II. 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 alkalies. The former, however, re-dissolve 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 alkali, is re-dissolved, 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. (*d.*) It gives up its acid on the application of heat, without decomposition; and an oxide of copper remains in the retort.

III. Copper dissolves readily in diluted nitric acid; and nitrous gas is evolved in great abundance. The salt, resulting from this combination, has the singular property of detonating with tin. When to the solution of this salt, a solution of potash is added in sufficient quantity, a blue powder is precipitated, consisting of the black oxide of copper combined with water, of which it contains 25 per cent. This substance has been called by Proust, hydrate of copper; but, more properly, by Mr. Chenevix, hydro-oxide of copper. The hydro-oxides may also be formed by a similar precipitation of other metallic solutions.

IV. Concentrated and boiling muriatic acid acts on copper; and a green solution is obtained. In this salt the copper is oxydized to its maximum. It is very soluble in water, and deliquescent. Another combination of this acid and metal, in which the latter is oxydized in an inferior degree, may be obtained, by mixing, in a mortar, 57½ parts of black oxide of copper, and 50 of copper, in fine powder (obtained by precipitation on a plate of iron), and dissolving this mixture in muriatic acid. When this salt is poured into water, a white powder is precipitated, because the excess of acid is removed, which is essential to solution.

V. When corroded by long continued exposure to the fumes of vinegar, copper is converted into verdegris.—The verdegris of commerce consists partly of an acetate, soluble in water, and partly of a sub-acetate. By solution in distilled vinegar and evaporation, it forms regular crystals, which are completely soluble in water.—These, distilled alone, yield concentrated acetic acid, and a combination of charcoal and oxide of copper remains in the retort.

VI. When the muriate of copper is mixed with a solution of prussiate of potash or of lime, a beautiful reddish brown precipitate is obtained, which has been recommended by Mr. Hatchett as a pigment.

VII. Copper combines with sulphur. When a mixture of three parts of the metal, in the state of fine filings, with one part of sulphur, is melted in a glass tube, at the moment of combination, a brilliant inflammation ensues, exceeding, in brightness, that produced by the fusion of iron and sulphur.

SECTION IX.

Iron.

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

When exposed to a stronger heat, this oxide is changed into a reddish-brown one, not attracted by the magnet, and containing 40 per cent. of oxygen. Long continued exposure to a humid atmosphere covers iron with a yellow oxide, which contains also a portion of carbonic acid.

2. Iron is oxydized 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 oxydized; and the vapour of water gives up its oxygen to red-hot iron, the hydrogen being liberated in an uncombined state.

II. 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 oxydized by the decomposition of the water, and this oxide 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 oxide of iron is thrown down by alkalies and by earths, varying in colour with the kind and state of the precipitant. Ammonia, added in excess, re-dissolves the precipitate.

(*c.*) When the iron, contained in this salt, is still farther oxydized, 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 oxydized to a certain degree.—Mere exposure to air is sufficient to precipitate an oxide of iron, and the same effect is rapidly produced by adding a little oxygenized 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 insoluble in alcohol; its solution in water is of a pale green colour; 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 oxygenized muriatic acid, or by nitric acid. The red sulphate may be changed into the green one by agitation, in contact with sulphuretted hydrogen gas.—

The common sulphate of iron is a mixture of these two in various proportions. (See *Ann. de Chimie*, vol. xxiii.)

(*d.*) The sulphate of iron is decomposed by heat alone. When distilled in an earthen retort, the sulphuric acid passes over, and an oxide of iron remains in the retort.

III. 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's Researches, 186.)

IV. 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 oxide 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 oxide of iron remaining.

(*d.*) It is decomposed by pure alkalies and earths, which abstract the prussic acid, and leave an oxide 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; still retaining, however, a considerable proportion of oxide of iron, which varies from 24 to 30 per cent. It is in fact, therefore, a triple prussiate of potash and iron; but as no combination of the two first is known, it may be termed, for the sake of brevity, prussiate of potash.

In Nicholson's Journal (4to. iv. 30.171.), I have given an improved process for preparing the triple prussiate of potash. The following, after trying various modes of preparation, I find to afford the purest test.

1. 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 wash-

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* This acid will be mentioned hereafter.

ings be all mixed together, and placed in an earthen dish in a sand-heat.—When the solution has become hot, add a little diluted 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 filter.

2. Prepare a solution of sulphate of copper in about four or six times its weight of warm water, and into the solution (1.) pour this, as long as a reddish-brown of 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.

3. Powder the precipitate, when dry, and add it by degrees to a solution of pure potash, prepared as described, p. 78. The prussic acid will leave the oxide of copper and pass to the alkali, forming a prussiate of potash as free from iron as it can be obtained.

4. 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 remaining liquid, add a solution of barytes in warm water (p. 81.) 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 alkali, either soda or ammonia may be substituted in the above process, if they be preferred. If a sufficient quantity of pure barytes cannot be had, the sulphate may be precipitated by acetate of barytes. The acetate of potash, thus formed, not being a crystallizable salt, remains in the mother-liquor.

(c.) When the prussiate of potash is mixed with sulphate of iron, in which the metal is as little oxydized 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.

(*g*.) The prussiate of potash decomposes all metallic solutions, excepting those of gold, platina, iridium, osmium, rhodium, tellurium, and antimony.

V. When sulphate of iron is mixed with an infusion of galls, we obtain a black solution, which is a new combination of oxide 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 oxide; for the less oxydized 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 oxydizes 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 oxide of iron is partly deoxydized. 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. (iv. 6.)

(*b*.) The combination of iron, forming ink, is destroyed by pure and carbonated alkalies. Apply a solution of alkali to characters written with common ink, the blackness will disappear, and the characters will become brown, an oxide of iron only remaining on the paper.

Alkalies, added cautiously to liquid ink, precipitate the black combination, but an excess re-dissolves 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 oxide 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 alkali of the soap abstracts the gallic acid, and leaves only an oxide of iron.

(*f.*) Ink is decomposed by oxygenized muriatic acid, which destroys the gallic acid, and the resulting muriatic acid dissolves the oxide 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.) This ink I have found extremely useful in writing labels for bottles which contain acids, or which are exposed to acid fumes in a laboratory.

VI. Iron is dissolved by water impregnated with carbonic acid. a few iron-filings, when added to a bottle of aerated 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.

VII. Iron combines with sulphur, [See Note 31.] and affords compounds; the characters of which vary greatly according to the proportions of their components. (*a.*) A paste of iron-filings, sulphur, and water, if in sufficient quantity, will burst, after some time, 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 exhibits a brilliant combustion. (*c.*) This sulphuret of iron, when moistened, rapidly decomposes oxygen gas. (*d.*) When diluted sulphuric or muriatic acid is poured on it, we obtain sulphuretted hydrogen gas.

These sulphurets are magnetic, unless they contain sulphur to the amount of 46 per cent.

VIII. Iron combines with carbon in various proportions; and the variety of proportion occasions very different properties in the compound. On these varieties, and the occasional combination of a small proportion of oxygen, depend the qualities of the different kinds of iron used in the arts, as cast-iron, steel, &c. &c. A distinct enumeration of these varieties, which would be foreign to the purpose of this work, may be found in Parkinson's Chemical Pocket-book, or in Thomson's Chemistry, vol. i. p. 166. The quantity of carbon, in the sub-carburets of iron, may be determined by solution in sulphurous acid, which dissolves the iron and sulphur, and has no action on carbon. An ingenious mode of analysis employed by Mr. Mushet, consists in ascertaining the quantity of litharge, which a given quantity of the iron under examination is capable of reducing, by fusion, to a metallic state.

Another combination of iron and carbon, which is a true carburet of iron, is the substance called *plumbago*, or black-lead, used in fabricating pencils, and in covering iron to prevent rust. By exposure to the combined action of heat and air, the carbon is burned off, and the oxide of iron remains. When mingled also with powdered nitrate of potash, and thrown into a crucible, a deflagration ensues; and an oxide of iron, equal to about 1-10th the weight of the plumbago, may be obtained by washing off the alkali of the nitre. From recent experiments of Messrs. Allen and Pepys, it appears that pure plumbago, when burnt in oxygen gas, leaves a residue of oxide of iron amounting only to about 5 per cent.

SECTION X.

Nickel.

I. 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.

Another process for purifying nickel, is given by Richter, in Nicholson's Journal, xii. 75. The properties of this metal in a state of purity, he describes as follows :

1. Its colour is intermediate between those of silver and tin.

2. It is not oxydized by exposure to the air.

3. It is perfectly malleable ; may be forged into bars when hot ; and hammered into plates when cold. When cast, its specific gravity is 8.279 ; and, when forged, 8.666.

4. In infusibility it appears to equal manganese.

5. In a sufficiently high temperature, its oxides are reducible without addition ; nor is it more tarnished by a strong heat than gold, silver, or platina. It ranks, therefore, among the noble or perfect metals.

6. The magnet not only acts on nickel, with a force little inferior to what it exerts on iron ; but nickel itself acquires polarity in the usual modes.

7. The sulphuric and muriatic acids have little action on nickel. Its appropriate solvents are the nitric and nitro-muriatic acids. The nitric solution has a beautiful grass-green colour. Carbonate of potash throws down an apple-green precipitate, which assumes a dark-grey colour when heated.

8. When pure ammonia is added to nitrate of nickel, a precipitate is formed, resembling that which is separated by ammonia from a solution of copper, but not of so deep a hue. This colour changes, in an hour or two, to an amethyst red, and to a violet ; which colours are converted to apple-green by an acid, and again to blue and violet by ammonia. If the precipitate retains

its blue colour, the presence of copper is indicated. (See Richter, in Nich. Journ. xii.)

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

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

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

SECTION XI.

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.

I. 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.

II. Tin is not oxydized by exposure to air with the concurrence of moisture; a property which is the foundation of its use in covering iron.

III. Tin amalgamates readily with mercury; and this compound is much used in the silvering of looking-glasses. It is formed by adding gradually three parts of mercury to twelve of tin melted in an iron ladle, and stirring the mixture.

IV. Tin dissolves in sulphuric acid, which takes up, when concentrated and heated, half its weight. It is dissolved also by this acid, diluted with a small proportion of water, and heated. During both these processes, sulphurous acid is disengaged; and, in the latter, a pellicle of sulphur forms on the surface of the solution, which precipitates on cooling.

V. Concentrated nitric acid attacks tin with great violence; and an imperfectly saturated solution is obtained. The diluted acid oxydizes tin, which, at the same moment, decomposes both the acid and water; and the azote and hydrogen, uniting, constitute ammonia.

VI. Muriatic acid, undiluted, is the proper solvent of tin. To one part of tin, in a tubulated retort, two parts of concentrated muriatic acid are to be added, and heat applied. The solution is complete; and, when finished, the liquid has an amber colour, and an offensive smell.—This solution is applied to important purposes in the art of dyeing. It has the property of reducing, to a minimum of oxydizement, those compounds of iron in which the metal is fully oxydized. For example, it reduces the yellow sulphate to the green. It is a test also of gold and platina, as already noticed.

VII. Tin may be brought to combine with the oxygenized muriatic acid, by first forming it into amalgam with mercury, triturating this with an equal weight of 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.

This compound, according to the researches of Adet, is an oxygenized muriate of tin, perfectly free from water, and having a strong affinity for that fluid. Hence arises its fuming property ; for the white vapours, which exhale when the bottle is unstopped, arise from the union of the salt with the humidity of the air.

VIII. The oxide of tin, combined with sulphur, affords a compound of a bright gold colour and lustre, which has hence been termed *aurum musivum.*

SECTION XII.

Lead.

I. 1. Lead, when melted, and exposed to the action of the air, becomes covered with a pellicle of oxide. By long-continued exposure to heat, [See Note 32.] it is converted into oxides of different colours. This oxydation it is difficult to exhibit on a small scale. The oxides 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 oxides of lead give up their oxygen on the application of heat. When distilled in an earthen retort they afford oxygen gas ; and still more readily when distilled with the sulphuric acid.

To obtain oxygen gas, concentrated sulphuric acid may be poured on the red oxide of lead, contained in a gas-bottle, and a gentle heat applied. The gas, thus obtained, after being agitated with water, is sufficiently pure for common purposes.

3. The oxides of lead are also reduced, by being ignited with combustible matter. Thus, when a mixture of red oxide of lead

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* For fuller information respecting the oxides of lead, consult Nich. Journ. viii. 280.

and charcoal is made red-hot in a crucible, a button of metallic lead will be found at the bottom of the vessel.

II. Pure water has no action on lead; but it takes up a small proportion of the oxide of that metal. When left in contact with water, and with the access of atmospherical air, lead soon becomes oxydized and dissolved, especially if agitation be used. Hence the danger of leaden pipes and vessels for containing water, which is intended to be drank. Water appears also to act more readily on lead, when impregnated with the neutral salts that are occasionally present in spring-water.*

III. Of all the acids the nitric acts most strongly on lead, nitrous gas being disengaged during the solution.—A portion of the lead, however, forms an insoluble grey powder, which is probably lead oxydized in too great a degree to be soluble in the acid. From this solution, sulphuric and muriatic acids throw down an insoluble precipitate. The muriate of lead, after being washed with distilled water and dried, and then fused in a crucible, forms a substance, which has the semi-transparency and tenacity of horn, and is called *plumbum corneum.*

IV. The oxides of lead decompose muriate 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 mixture becomes dry. The alkali will be disengaged, and the muriatic acid will unite with the oxide of lead. Wash off the alkali, dry the white mass, and fuse it in a crucible. It will form the pigment called mineral, or patent yellow.

V. Lead, when exposed to the vapour of vinegar, is slowly corroded into a sub-acetate. This, when dissolved in distilled vinegar and crystallized, forms acetate of lead, or sugar of lead. This acetate of lead, and indeed all the soluble salts of lead, are decomposed by sulphuretted hydrogen gas. Hence characters, written with a solution of acetate of lead, become legible on exposure to sulphuretted hydrogen gas.

VI. The oxides of lead have the property of uniting with silver by fusion; and, when added to the ingredients of glass, they increase its transparency, and render it less brittle, so as to admit of being ground and polished. Hence an oxide of lead is an essential constituent of flint-glass.

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* On the presence of lead in water, consult Dr. Lambe's "Researches respecting Spring Water." 8vo. London. Johnson.

SECTION XIII.

Zinc*.

I. Zinc is melted by a moderate heat; and the fused mass, on cooling, forms regular crystals.

II. Though scarcely altered by exposure to the air at a low temperature, yet it is rapidly oxydized by one amounting to ignition.

When kept in a degree of heat, barely sufficient for its fusion, zinc becomes covered with a grey oxide. But when thrown into a crucible, or deep earthen pot, heated to whiteness, it suddenly inflames; burns with a beautiful white flame; and a white and light oxide sublimes, having a considerable resemblance to carded wool. This oxide, however, when once deposited, is no longer volatile; but, if exposed to a violent heat, runs into glass.

III. Zinc readily dissolves in sulphuric, nitric, and muriatic acids. With nitric acid, it yields nitrous gas, if the acid be concentrated; or nitrous oxide, if diluted. Sulphuric and muriatic acids, diluted with water, evolve, during their action on this metal, hydrogen gas; and the gas, when obtained, holds in combination a portion of the metal. A stream of it, burned in Cuthbertson's apparatus (pl. iv. fig. 34.), has been found, if recently prepared, to occasion the fusion of the platina wire, though the pure gas is destitute of this property. This hydrogen gas, holding zinc in solution, may also be obtained by a process of Vauquelin. A mixture of the ore of zinc, called blende, or calamine, with charcoal, is to be put into a porcelain tube, which is to be placed horizontally in a furnace, and, when red-hot, the vapour of water is to be driven over it. The gas, that is produced, however, is a mixture of carbonic acid, carburetted hydrogen, and hydro-zincic gas. The zinc is deposited on the surface of the water, by which this gas is confined; but, if burned when recently prepared, the gas exhibits, in consequence of this impregnation, a blue flame.

IV. The solution of zinc in sulphuric acid shoots into regular crystals. This salt is readily soluble; and its solution is not precipitated by any other metal. The muriate of zinc yields, when evaporated, an extract of thick consistence, having the viscidity of bird-lime.

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* The discovery of the malleability of zinc, when heated, is announced in Phil. Mag. vol. xxiii.

V. Zinc is oxydized also, when boiled with solutions of pure alkalies; and a portion of the oxide is retained in solution.

VI. It is oxydized when mixed with nitre, and projected into a red-hot crucible. In this case a violent detonation ensues.

SECOND CLASS.

METALS THAT ARE BRITTLE AND EASILY FUSED.

SECTION XIV.

Bismuth.

I. Bismuth is one of the most fusible metals; and it forms, more readily than most other metals, distinct crystals by slow cooling.

II. When kept melted at a moderate heat, it becomes covered with an oxide of a greenish-grey or brown colour. In a more violent heat it is volatile, and may be sublimed in close vessels; but, with the access of air, it emits a blue flame, and its oxide exhales in the form of a yellowish smoke, condensible by cold bodies. This oxide is very fusible; and is convertible, by heat, into a yellow transparent glass.

III. Sulphuric acid acts on bismuth, and sulphurous acid is disengaged. A part of the bismuth is dissolved; and the remainder is changed into an insoluble oxide.

IV. Nitric acid dissolves bismuth with great rapidity. To one part and a half of nitric acid, add, at distant intervals, one of bismuth, broken into small pieces. The solution is crystallizable. It is decomposed when added to water; and a white substance is precipitated, called magistery of bismuth, or pearl-white. This pigment is defective, inasmuch as it is liable to be changed by sulphuretted hydrogen, and by the vopours of putrefying substances in general.

V. Muriatic acid acts on bismuth. The compound, when deprived of water by evaporation, is capable of being sublimed, and affords a soft salt, which deliquesces into what has been improperly called butter of bismuth.

VI. Bismuth is capable of forming the basis of a sympathetic ink. The acid, employed for this purpose, must be one that does not act on paper, such as the acetic. Characters written with this solution become visible, when exposed to sulphuretted hydrogen.

SECTION XV.

Antimony.

I. Antimony, as it occurs under that name in the shops, is a natural compound of the metal with sulphur. To obtain it in a metallic state, the native sulphuret is to be mixed with two-thirds its weight of acidulous tartrite of potash (in the state of crude tartar), and one-third of nitrate of potash deprived of its water of crystallization. The mixture must be projected, by spoonfuls, into a red-hot crucible; and the detonated mass poured into an iron-mould greased with a little fat. The antimony, on account of its specific gravity, will be found at the bottom adhering to the scoriæ, from which it may be separated by the hammer. Or three parts of the sulphuret may be fused in a covered crucible with one of iron-filings. The sulphur quits the antimony, and combines with the iron.

II. Antimony in its metallic state (sometimes called *regulus of antimony*) is of a silvery white colour, very brittle, and of a plated or scaly texture.

III. It is fused by a moderate heat; and crystallizes, on cooling, in the form of pyramids. In close vessels it may be volatilized, and collected unchanged.

IV. It undergoes little change when exposed to the atmosphere at its ordinary temperature; but when fused, with the access of air, it emits white fumes, consisting of an oxide of the metal. This oxide had formerly the name of *flowers of antimony.*

V. Antimony combines with phosphorus and sulphur. With the latter an artificial sulphuret is formed, exactly resembling the native compound, which last may be employed, on account of its cheapness, for exhibiting the properties of this combination of antimony.

1. When native sulphuret of antimony (frequently called crude antimony) is slowly roasted in a shallow vessel, it gradually loses its sulphur, the metal attracts oxygen, and is converted into a grey oxide. This, being melted in a strong heat, acquires a reddish colour, and runs into a glassy substance, transparent at its edges, and termed *glass of antimony**.

2. When fused with potash, a triple compound is formed, composed of alkali, sulphur, and antimony. Or the combination may be effected, in the humid way, by boiling the powdered native sulphuret with pure potash. The solution, on cooling,

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* Glass of antimony Vauquelin finds to contain 12 per cent. of silex.

deposits an hdyro-sulphuretted oxide, in which the oxide prevails, called Kermes *mineral.* The addition of a dilute acid to the cold solution, precipitates a compound, having the same ingredients, but a larger proportion of sulphur, and called *golden sulphur of antimony.*

3. When the sulphuret of antimony is detonated with powdered nitre, the sulphur is oxygenated by the oxygen of the nitric acid; sulphate of potash is formed, and an oxide of antimony is obtained, varying in its degree of oxygenizement, with the proportion of nitre employed. The oxide remains, after washing away the sulphate with boiling water. If four times its weight of nitre be employed, the metal gains 32 per cent. of oxygen, and acquires somewhat of the character of an acid; since it forms, with potash, a crystallizable compound.

VI. Antimony is dissolved by most of the acids. Sulphuric acid is decomposed; sulphurous acid being disengaged, and an oxide formed, of which a small proportion only is dissolved by the remaining acid. Nitric acid dissolves this metal with great vehemence; muriatic acid acts on it by long digestion; but the most convenient solvent is the nitro-muriatic acid, which, with the aid of heat, dissolves it from the native sulphuret. With oxygenized muriatic acid, it forms a compound of a thick consistence, formerly called butter of antimony. This may be formed, by exposing black sulphuret of antimony to the fumes of oxygenized muriatic acid, and subsequent distillation; or by distilling the powdered regulus with twice its weight of corrosive muriate of mercury. The metal becomes highly oxydized, and unites with muriatic acid in its simple state. On pouring this compound into water, a white oxide falls down, called powder of algaroth.

VII. Antimony is susceptible of various states of oxydizement. The first oxide may be obtained by washing algaroth powder with a little caustic potash. It is composed of 18½ oxygen, and 81½ metal. That formed by the action of nitric acid on antimony contains 77 metal, and 23 oxygen.

SECTION XVI.

Tellurium.

I. Tellurium was discovered, by Klaproth (Contributions, ii. 1.) in an ore of gold. His process, for extracting it, consists in the solution of the ore by nitro-muriatic acid, dilution with water, and the addition of pure potash, which throws down all the metals that are present; and, when added in excess, re-dissolves a white precipitate, which it at first occasions. To the alkaline solution, muriatic acid is then added; a precipitate again appears; and this, when dried, and heated with 1-12th its weight of charcoal, or with a small quantity of oil, in a glass retort, yields tellurium, in the form of small brilliant metallic drops, lining the upper part of the body of the retort.—One hundred parts of the ore yield above 90 of tellurium.

II. 1. The colour of this metal is tin-white, verging to lead-grey; it has considerable lustre, and a foliated or scaly fracture. It is very brittle; is fusible at a temperature below ignition; and, excepting osmium and quick-silver, is the most volatile of all metals. It is the lightest of the metals, having the specific gravity of only 6.185.

2. It is oxydized when heated in contact with air; and burns with a sky-blue flame, edged with green. Upon charcoal, before the blow-pipe, it inflames with a violence resembling detonation; exhibits a vivid flame; and entirely flies off in a grey smoke, having a peculiarly nauseous smell. Its oxide is not reduced without the addition of combustible matter.

3. It is soluble in nitric and nitro-muriatic acids. The saturated solution is decomposed by the mere addition of water, which throws down a white powder; but this is again dissolved on adding more water. From its solutions it is precipitated in a metallic form, by iron, zinc, tin, and even by muriate of tin. Carbonated and pure alkalies precipitate the telluric oxide of a white colour; and the oxide is re-dissolved by an excess of alkali or carbonate. Alkaline sulphurets throw down a dark-brown or blackish precipitate. Tincture of galls produces a flocculent yellow precipitate. The solutions of this metal in acids are not decomposed by prussiate of potash; a property which tellurium possesses in common with gold, platina, iridium, osmium, rhodium, and antimony.

SECTION XVII.

Arsenic.

I. Arsenic, as it is to be found in the shops, occurs in the state of a white oxide, from which the metal may be obtained by the following process. Mix two parts of the white oxide with one part of black flux (prepared by detonating, in a crucible, one part of nitre with two of crystals of tartar); and put the mixture into a crucible. Invert over this another crucible;

lute the two together, by a mixture of 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 state of metallic brilliancy.

II. Arsenic is oxydized by mere exposure to the atmosphere. It soon becomes tarnished; loses its metallic lustre; and is changed into a blackish oxide.

III. It is readily fusible, and is volatilized at 356°. In close vessels it may be collected unchanged; but when thrown on a red-hot iron, it burns with a blue flame and a white smoke; and a strong smell of garlic is perceived.

IV. All the mineral acids act on arsenic; but not considerably, unless they are heated. In the oxygenized muriatic acid gas, however, arsenic burns vehemently.

V. A mixture of oxy-muriate of potash and arsenic furnishes a detonating compound, which takes fire with the rapidity of lightning. The salt and metal, first separately powdered, may be mixed by the gentlest possible triture, or rather by stirring them together on paper with a knife point. If two long trains be laid on a table, the one of gunpowder and the other of this mixture, and they be in contact with each other at one end, so that they may be fired at once, the arsenical mixture burns with the rapidity of lightning, while the other burns with comparatively extreme slowness.

VI. Arsenic has the property of giving a white stain to copper. Let a small bit of metallic arsenic be put between two small plates of copper; bind these closely together with iron-wire; and heat them, barely to redness, in the fire. The inside of the copper-plates will be stained white.

VII. The white oxide of arsenic has the following properties:

1. It has an acrid taste, and is highly poisonous.

2. It is soluble in water, which, at the ordinary temperature, takes up 1-80th. According to La Grange, it is soluble in 1-24th of cold water, or 1-15th of hot.

3. Oxide of arsenic combines with the pure alkalies to saturation; and hence it fulfils one of the principal functions of an acid. It has therefore been called *arsenous acid*, and its compounds *arsenites*. They may be formed by simply boiling the arsenous acid with a pure alkaline solution.

4. The arsenous acid, by distillation with sulphur, affords either a yellow substance, called orpiment, or a red one, termed realgar. Both these compounds are sulphuretted oxides of

arsenic, varying in the proportion of their components. The hydro-sulphurets, also, throw down a yellow precipitate from solutions of arsenous acid. Sulphate of copper, mixed with arsenite of potash, gives a beautiful precipitate, called, from its discoverer, Scheele's green.

5. By repeated distillation with nitric acid, arsenous acid is changed into *arsenic acid.* The same change is effected, also, by exposure to the vapour of oxygenized muriatic acid, and the expulsion, by heat, of the common muriatic acid. By both these processes, a white concrete substance is obtained, termed arsenic acid.

VIII. 1. The arsenic acid has a sour, and at the same time, a metallic taste. It reddens vegetable blues; attracts humidity from the atmosphere; and effervesces strongly with solutions of alkaline carbonates. With alkalies, earths, and oxides, it constitutes a class of salts called arsenates. The arsenate of potash may be obtained in a more simple manner, by detonating, in a crucible, a mixture of nitrate of potash with arsenous acid.

2. When tin is dissolved in arsenic acid, an inflammable gas is disengaged, as was observed by Scheele, consisting of hydrogen gas, holding arsenic in solution. It may be obtained, also, by adding powdered metallic arsenic to a mixture of diluted sulphuric acid and zinc filings.

The gas (to which, perhaps, the name of *arsenuretted hydrogen* is best adapted) has the following properties:

(*a.*) It is a permanently elastic and invisible fluid, of the specific gravity, compared with common air, of 0.5293.

(*b.*) It has a fetid smell, resembling that of garlic.

(*c.*) It extinguishes burning bodies.

(*d.*) It is not absorbed by water in any notable degree; and has no effect on the blue colours of vegetables.

(*e.*) It burns with a lambent white flame, and a disagreeable odour; and emits, during combustion, fumes of arsenous acid.

(*f.*) When mingled with oxygenized muriatic acid gas, heat is produced, a diminution ensues, and metallic arsenic is deposited. Soap bubbles, blown with a mixture of this and oxygen gases, burn with a blue flame, a white smoke, and a strong alliaceous smell.

(*g.*) A stream of arsenuretted hydrogen gas, issuing from a bladder fitted with a stop-cock, and set on fire in a large receiver filled with oxygen, burns with a blue flame of uncommon splendour.

(*h.*) One cubic inch of the gas contains about 1-4th of a grain of metallic arsenic.

For its remaining properties, consult Tromsdorff's Memoir in Nich. Journ. vi. 200.

THIRD CLASS.

BRITTLE AND DIFFICULTLY FUSED.

SECTION XVIII.

Cobalt.

I. Cobalt may either be obtained from a substance, which may be purchased under the name of Zaffre, by fusing the zaffre with three times its weight of black flux ; or it may be purchased, at a moderate price, in a metallic form.

To obtain cobalt in a perfectly pure state, Tromsdorff recommends, that the zaffre should be, three times successively, detonated with one-fourth its weight of dry nitre, and one-eighth of powdered charcoal. After the last of these operations, the mass is to be mixed with an equal weight of black flux, and the cobalt reduced. The metal is then pulverized, and detonated with thrice its weight of dried nitre. This oxydizes the iron to its maximum ; and acidifies the arsenic ; which last unites with the potash. Wash off the arsenate of potash, and digest the residue in nitric acid. This will take up the oxide of cobalt, and leave the oxide of iron. Evaporate to dryness ; re-dissolve in nitric acid ; filter the solution ; and decompose it by a solution of potash. The oxide of cobalt, now obtained, may be reduced by the black flux, as before directed.

II. Cobalt has a white colour, inclining somewhat to pink. By exposure to the atmosphere it is tarnished, but not oxydized to any extent. In an intense heat it burns with a red flame ; but, if pure, it is not easily oxydized by a moderate temperature. Its oxide is of a deep blue, approaching to black.

III. Cobalt is magnetic ; at least this property is generally imputed to it even by late writers ; But Mr. Chenevix suspects that it is owing to the presence of a small admixture of iron.

IV. The best solvents of cobalt are the nitric and nitro-muriatic acids ; and the solutions have the singular property of forming sympathetic inks. One part of cobalt, or, still better, of zaffre, may be digested, in a sand-heat, for some hours, with four parts of nitric acid. To the solution, add one part of muriate of soda; and dilute with four parts of water. Characters written with this solution 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.

V. Oxide of cobalt is precipitated by carbonated alkalies from the nitric solution, at first of a peach-flower colour, and afterwards of a lilac hue.

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

Cobalt, when oxydized, is the basis of zaffre. This is generally prepared by roasting, from the ore, its volatile ingredients; and mixing with the remainder three parts of sand, or calcined flints. Zaffre, when fused, forms a blue glass; which, when ground and washed, is the substance termed smalts, used as a colouring substance, and for imparting a blue colour to glass.

SECTION XIX.

Manganese.

I. 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 oxide, finely powdered, with pitch, making it into a ball, and putting this into a crucible, with powdered charcoal, 1-10th of an inch thick on the sides, and 1-4th 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.

II. 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.

When heated with the access of air, it passes through successive shades of black, and finally acquires a green colour. (La Grange, ii. 64.)

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

III. The metal is soluble in acids, but most readily in the nitrous. The muriatic solution is precipitated by the addition of water only. It is precipitated by alkalies in the form of a white powder.

IV. The black oxide 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.

V. The black oxide of manganese is dissolved by the muriatic acid ; but, before solution, it yields part of its oxygen to one portion of the muriatic acid, which escapes in an oxygenized state, (see chap. xiii.) The solution has a brownish colour. Alkalies throw down from it a white precipitate, which, by exposure to the air, becomes yellow, and finally black.

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

VII. The black oxide 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 re-produced by the exterior one, or by a small particle of nitre. (See Klaproth, vol. i. p. 243. a.)

VIII. 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-oxydized 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 a purple ; and a still larger quantity to a beautiful deep purple.

The experiment may be varied, by putting equal quantities of this substance into two separate glass vessels, and pouring on the one hot, and on the other cold, water.—The hot solution has a beautiful green colour, and the cold one is of a deep purple. The same material, with water of different temperatures, assumes various shades of colour, depending on the state of oxydizement of the metal. Hence this has been termed the chameleon mineral. This property has been destroyed by a very small quantity of sulphuret of potash.

IX. 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 de-oxydation of the metal by the sun's rays.

SECTION XX.

Chrome.

This metal is found in an acidified state, and combined with oxide of lead, in the red-lead ore of Siberia; in the state of an oxide, in the green ore accompanying the red one; and in the emerald, to which it communicates its green colour.

I. To separate the chronic acid, the red-lead ore, reduced to powder, is boiled with twice its weight of carbonate of potash. An orange-yellow solution, composed of potash and chronic acid, is thus obtained; and when, to this, a mineral acid is added, and the liquor is evaporated, we obtain, 1. the salt formed by the acid, which has been united with the potash; 2. the acid of chrome, in long ruby-coloured prisms. From this acid the chrome may be obtained by heating it with charcoal, in the manner already often described. In the crucible a metallic mass is found, of a greyish-white colour, formed of a number of needles crossing each other.

II. This metal is very brittle, infusible, and fixed.

III. It is susceptible of three states of oxydizement.—The first oxide is green, the second brown, and a further dose of oxygen gives the chromic acid.

IV. The nitric acid alone exerts any remarkable action on this metal. Repeated distillation, with this acid, changes chrome into chromic acid, combinable with alkalies. The chromates of alkalies precipitate the salts of lead, of a beautiful yellow colour; which, if it could be procured in sufficient quantity, would be highly valuable in painting. Mercury is thrown down, of a cinnabar-red colour; silver, of a carmine-red; and all its metallic combinations are distinguished by peculiar brilliancy of colour. The emerald derives its colour from the *oxide* of chrome; and the ruby from the *acid.* This property of imparting colour has suggested its name.

SECTION XXI.

Molybdena.

I. The ore of molybdena was long mistaken for plumbago, or carburet of iron, to which it bears, externally, a strong resemblance. It is, in fact, a combination of sulphur and the oxide of molybdena. These two components may be separated, by repeated distillation with nitric acid. To the ore of molybdena, in a retort, six times its weight of nitric acid are to be added, and the mixture distilled to dryness. This process must be repeated four or five times; and, at its close, both the sulphur and molybdena will be acidified. The sulphuric acid is expelled by heating the mass in a crucible; and any remaining portions are to be washed off with distilled water. The residue is a white heavy powder; which has an acid and metallic taste; is soluble in 560 parts of water; and forms salts with the alkalies and earths. The acid is reduced by making it into a paste with oil, and exposing it, bedded in charcoal in a crucible, to an intense heat.

II. Molybdena has a whitish-yellow colour, but its fracture is a whitish grey. It has not, hitherto, been obtained in any form, but that of small brittle grains. It is almost infusible by any artificial heat.

III. It is readily oxydized when heated in contact with air, and is converted into a white oxide, which is volatilized in small brilliant needle-shaped crystals. This oxide has acid properties.

IV. According to Mr. Hatchett's experiments molybdena may be oxydized in four different degrees. 1. A black oxide is obtained from molybdenic acid, ignited with charcoal powder. 2. A blue one may be obtained by the same process not carried so far; or by immersing a plate of tin in a solution of the acid. 3. The third oxide has a green colour; and, having acid properties, is termed molybdenous acid. The fourth is the yellow acid obtained by the process already described.

V. The nitric, nitro-muriatic, and oxy-muriatic acids, are the only ones that act on molybdena.

VI. The muriatic, and other acids, act on its oxides, and afford blue solutions.

VII. Molybdena unites readily with sulphur, and composes a substance, similar to the one from which the metal was originally obtained.

VIII. The molybdenic acid combines with alkalies, earths, and some of the imperfect metals. A small rod of zinc or tin is acted upon by a solution of the acid, which becomes blue, in consequence of the loss of a portion of its oxygen. The acid precipitates nitrates of silver, mercury, and lead; muriate of lead, and nitrate and muriate of barytes. Recent muriate of tin throws down, from the solution of molybdenate of potash, a beautiful blue precipitate

SECTION XXII.

Uranium.

I. This metal was discovered by Klaproth, in a mineral which contains uranium combined with sulphur. The metal is separated from the sulphur, first by roasting; then dissolving the ore in nitro-muriatic acid, and precipitating by an alkali. An orange-coloured precipitate is obtained, which is an oxide of uranium. This may be reduced to a metallic form, in the same manner as the molybdenic acid.

II. Uranium is of a dark grey colour; and internally of a reddish brown. It has only been obtained in small grains of considerable hardness. Its fusion is very difficultly effected.

III. The metal is soluble only in nitric acid.

IV. Its oxide is of a yellow colour, and dissolves in acids. It is precipitated by alkalies; and is thrown down, of a reddish brown colour, by prussiates. Sulphuret of ammonia gives a brownish yellow precipitate; and tincture of galls, a chocolate brown one.

V. The oxide of uranium is insoluble in alkalies, which distinguishes it from the oxide of tungsten. It is soluble, however, by alkaline carbonates.

SECTION XXIII.

Tungsten.

I. Tungsten may be obtained from two different minerals. The one, consisting of the tungstic acid, united with lime, is called simply tungsten. In the other, termed Wolfram, it is united with iron and manganese. Its extraction from the former is the most simple process. One part of the tungstate of lime, and four of carbonate of potash, are fused together, and tho mass is dissolved in 12 parts of boiling water. Nitric acid is then added, which unites with the potash, and precipitates tungstic acid. This acid, when reduced in the usual manner, yields tungsten; but the process of its reduction is a very difficult one, and frequently fails of success.

The tungstic acid may, also, be obtained from Wolfram, by fusion with three times its weight of nitrate of potash; or with twice its weight of carbonate of potash. The fused mass, dissolved in boiling water, and filtered, gives, on the addition of nitric acid, a precipitate of tungstic acid; or Wolfram, reduced to a fine powder, may be boiled with three times its weight of muriatic acid. As soon as the acid becomes hot, a yellow powder appears, and the liquid becomes brown. When cold, decant the clear liquid, and wash the sediment repeatedly with water; then digest it, for some hours, with liquid ammonia, which will take up a part. Repeat these operations, till they cease to act on the substance. Evaporate the ammoniacal solution to dryness, and calcine the salt. The acid of tungsten remains, in the proportion of more than half the weight of Wolfram which has been employed.

II. Tungsten has the following characters:

1. It has a greyish white colour, like that of iron, and a good deal of brilliancy. It is not magnetic.

2. It is extremely hard and brittle. It requires, for fusion, a temperature of at least 170° Wedgewood.

3. It is oxydized by the action of heat and air. Its first oxide is black. The second is yellow, and is commonly termed tungstic acid.

4. The tungstic acid has no taste; is insoluble in water; but remains suspended in it, and in this state has no action on vegetable colours. Exposed to heat in a platina spoon, it assumes a deep green colour. Calcined with the contact of air, its yellow colour becomes deeper, and passes to a green, and, after some hours, grey. The deficiency of several acid properties has induced Vauquelin to withdraw it from the class of acids, and to arrange it among the oxides. It combines with alkalies; but so do the oxides of tin, zinc, antimony, and arsenic.

FOURTH CLASS.

REFRACTORY METALS.

SECTION XXIV.

Titanium.

I. Titanium is obtained from a mineral found in Hungary, &c. called red schorl, or titanite; and, also, in a substance from Cornwall, termed menachanite. It was in the latter substance that it was originally discovered by Mr. Gregor of Cornwall; and its characters have since been more fully investigated by Klaproth, Vauquelin and Hecht, Lovitz, and Lampadius. To separate it from the first compound, the mineral is to be reduced to powder, and fused with twice its weight of potash. When the fused mass, after cooling, is dissolved in water, a white oxide of titanium remains.

Menachanite is to be first fused with potash in a similar manner; and to the alkaline solution, muriatic acid is to be added. This dissolves the oxide of iron, and precipitates the white oxide of titanium, still, however, contaminated by some iron.

II. The oxide of titanium is reduced, by exposure to an intense heat, moistened with oil, and surrounded by powdered charcoal. A blackish blistered substance is obtained, some points of which have a reddish colour. Lampadius states its colour to be that of copper, but deeper; and its lustre to be considerable. It is brittle, but when in thin plates, has considerable elasticity. When this is boiled with nitric acid, no remarkable effect ensues, but the bright spots disappear, and are succeeded by a white compound. Nitro-muriatic acid forms, also, a white powder, which remains suspended in it. Sulphuric acid exhibits a similar appearance; sulphurous acid is disengaged; and the titanium is partly changed to a white oxide, and partly dissolved. Muriatic acid dissolves titanium, but not its oxide.

III. The solution of titanium gives a white precipitate with carbonates of alkali; a grass green, mixed with brown, with prussiate of potash; and a dirty dark green, with hydro-sulphurets. Infusion of galls precipitates a reddish brown substance, which, if the solution be concentrated, has the appearance of coagulated blood. A rod of tin, immersed in the solution, imparts to the liquid around it a fine red colour; and a rod of zinc a deep blue one.

IV. Titanium tarnishes by exposure to the atmosphere, and is oxydized when heated with access of air. It is susceptible of three stages of oxydizement. The first oxide is blue or purple, the second red, and the third white.

SECTION XXV.

Columbium.

This metal was discovered by Mr. Hatchett, in a mineral belonging to the cabinet of the British Museum, supposed to be brought from Massachusetts, in North America. By alternate fusion with potash, and digestion with muriatic acid, the mineral was decomposed; the acid combining with oxide of iron, and the alkali with a peculiar metallic acid, separable by the addition of diluted nitric acid, which threw down a copious white sediment.

This acid has not yet been reduced; but from its properties, there can be little doubt that it has a metallic base. It is insoluble in nitric acid; but when fresh precipitated, it combines both with the sulphuric and muriatic. It unites also with alkalies: and both solutions are colourless. Prussiate of potash gives an olive-coloured precipitate; tincture of galls, a deep orange; and hydro-sulphuret of ammonia, one of a chocolate colour.

SECTION XXVI.

Tantalium.

This metal was discovered by Mr. Ekeberg, an eminent Swedish chemist, in two different fossils, both of which are found in Finland. In the one it occurs combined with iron and manganese; in the other, with the earth called yttria. (See *Annales de Chimie*, xliii. 281.) From these ores it is obtained, by treating them alternately with caustic fixed alkali, and muriatic or nitro-muriatic acid. The alkaline solution, being supersaturated with an acid, lets fall a white powder which is oxide of tantalium. The following are the characteristic properties of tantalium, as enumerated by Mr. Ekeberg:

1. It is not soluble in any acid, in whatsoever state the mineral is taken, and whatever means are employed.
2. Fixed alkalies attack it, and dissolve a considerable quantity, which may afterwards be precipitated by acids.
3. The oxide of this metal is white, and does not acquire any colour, by exposure to a high temperature with access of air. Its specific gravity, after being made red-hot, is 6.500.
4. It melts with phosphate of soda, and with borax, but does not impart to them any colour.
5. The oxide of tantalium, ignited with charcoal, melts and agglutinates. It then presents a metallic lustre, and a shining fracture of a greyish black colour. Acids change it again into a white oxide.

Though the oxides of tin and of tungsten are equally soluble with that of tantalium in fixed alkalies, yet the former is easily reduced, furnishing a ductile metal; and the oxide of tungsten dissolves in ammonia, is changed to a yellow colour by acids, and communicates colour to phosphate of soda and borax. The oxide of titanium differs from this, in being soluble by acids, and in tinging borax and phosphoric salts, when fused with them.

SECTION XXVII.

Cerium.

I. Cerium has been lately discovered, by Messrs. Berzelius and Hisenger of Stockholm, in a mineral from Bastnas, in Sweden, which had been supposed to be an ore of tungsten. This discovery has been since confirmed by the unquestionable testimony of Vauquelin; who, after a careful examination of the mineral, concurs in opinion, that it contains the oxide of an unknown metal. From the planet Ceres, discovered about the same period, it has been called Cerium; and the mineral that contains it is termed Cerite. (See Nich. Journ. XII.)

II. To obtain the oxide of this new metal, the cerite is dissolved in nitro-muriatic acid, after being calcined and pulverized. The solution is filtered, neutralized with pure potash, and then precipitated by tartrite of potash. This precipitate, well washed, and afterwards calcined, is the oxide of cerium.

III. Cerium appears to be susceptible of two stages of oxydizement; the first oxide being white, and the second of a fallow red. The white oxide, by calcination, becomes red.

IV. Sulphuric acid, diluted with four times its weight of water, dissolves the red oxide. The solution, on being evaporated, yields crystals, some of which are orange, and others have a lemon-yellow colour. The sulphate is soluble only by an excess of acid. Its taste is saccharine mixed with acid.

V. Sulphuric acid readily unites with the white oxide; the solution is nearly colourless, but has a slight rosy tinge. It has a saccharine taste, unmixed with acidity, and yields white crystals.

VI. Nitric acid unites most easily with the white oxide. The solution is very sweet, and is not crystallizable. When decomposed by heat, it leaves a brick-coloured oxide.

VII. Muriatic oxide dissolves the red oxide; and the solution crystallizes confusedly. The salt is deliquescent; soluble in an equal weight of water; and in three or four parts of alcohol. When this solution is concentrated, it burns with a yellow sparkling flame.

An infusion of galls produces, in muriate of cerium, a yellowish precipitate not very abundant. A few drops of ammonia throw down a very voluminous one of a brown colour, which becomes black and brilliant, by desiccation. By the action of heat, it assumes a brick-red colour.

VIII. Oxide of cerium unites readily with carbonic acid. This union is best effected, by precipitating a solution of the oxide with carbonate of potash. An effervescence ensues; and a white and light precipitate is formed, which assumes, on drying, a silvery appearance.

IX. Sulphuretted hydrogen does not unite with cerium.

X. The attempts of Vauquelin to reduce the oxide of cerium produced only a small metallic globule, not larger than a pin's head. This globule was not acted upon by any of the simple acids; but it was dissolved, though slowly, by nitro-muriatic acid. The solution was reddish, and gave traces of iron; but it also gave evident marks of cerium, by the white precipitate which tartrite of potash and oxalate of ammonia threw down. The metallic globule, also, was harder, whiter, much more brittle, and more scaly in its fracture, than pure cast-iron.

XI. Hence cerium appears to be a volatile metal, unless it is volatilized in the state of an oxide, which remains to be ascertained by future experiments.

CHAPTER XIX.

VEGETABLE SUBSTANCES.

SECTION I.

Vegetable Extract.

For the purpose of exhibiting its properties, extract may be obtained by evaporating, in a temperature below 212°, an infusion of saffron, prepared with boiling distilled water. It has the following properties:

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

2. It is soluble in cold water, but more copiously in hot. Hence the decoctions of certain substances (Peruvian bark for example) become turbid on cooling. The solution, exposed for a long time to the air, acquires a mouldy pellicle, and undergoes a sort of putrefaction.

3. When a solution of extract is slowly evaporated, it affords a semi-transparent mass; but rapid evaporation renders it perfectly opaque. By repeated solutions in water, and evaporations, it acquires a deeper colour, and loses its property of being solu-

ble in water, apparently in consequence of absorbing oxygen from the air.

4. Extract, exposed to the atmosphere, slowly imbibes moisture; or is imperfectly deliquescent.

5. It is soluble in alcohol and in liquid alkalies, but not in acids, which last even precipitate it from its solution in water. It is insoluble, also, in ether.

6. Oxygenized muriatic acid, poured into a solution of extract, precipitates a dark yellow powder, which is no longer soluble in water, but dissolves in hot alcohol.

7. Extract has an affinity for alumine. When the sulphate or muriate of this earth is poured into one of extract, a precipitate appears, especially if the mixture be boiled. When linen or woollen thread, previously impregnated with a solution of alum, is boiled with a solution of extract, the thread is dyed a fawn colour, and the extract disappears in great part from the liquor.

8. Muriate of tin, and several other metallic salts, also precipitate extract, their oxides forming with it insoluble compounds.

9. Extract is not precipitated by a solution of tan.

SECTION II.

Mucilage, or Gum.

This substance, in a solid state, is generally known by the name of gum. Gum arabic may be taken as an example. It appears, however, from Dr. Bostock's experiments, that there is considerable variety in the chemical properties of different mucilages.

1. Gum is dry, brittle, and insipid, and undergoes no change by exposure to the atmosphere, except that the action of light destroys the yellow colour, which it frequently exhibits.

2. It is readily soluble in water, and forms a viscid solution, which may be kept a long time without undergoing any change; but finally becomes sour.

3. It is insoluble in alcohol and in ether, the former of which separates it from water.

4. It is precipitated from water, in a thick curdy form, by acetate of lead; and is thrown down by the red sulphate of iron, in the state of a brown semi-transparent jelly. Several other salts, also, have a similar effect, as may be seen in a table, in the 5th vol. o Thomson's Chemistry, p. 39, 3d. edit. The effects

of re-agents on a solution of gum have been lately investigated, also, by Dr. Bostock; see Nich. Journ. xviii. 28.

5. It is soluble in pure alkalies, and is precipitated by acids. Of the earths, silex seems to have the strongest affinity for it; a solution of silicated alkali precipitating a very dilute solution of gum. (Thomson.) Dr. Duncan jun. however, informs me, that this precipitate is produced only by solutions of the lighter coloured specimens of gum, which have different properties from those of darker colour.

6. Diluted acids dissolve gum unchanged, and the concentrated ones decompose it. Strong sulphuric acid converts it into water, acetous acid, and charcoal; nitric acid changes gum into oxalic acid; and oxygenized muriatic acid into citric acid.

7. Gum and sugar readily combine; and by gentle evaporation of their mixed solutions, a transparent substance is obtained. From this, alcohol separates a part of the sugar, but the remainder continues in combination, and forms a substance, resembling that of which the nests of wasps are composed.

8. Gum, when submitted to destructive distillation in a retort, yields an acid, formerly called the pyro-mucous, but now ascertained to be merely the acetic, holding in solution a portion of essential oil. Carburetted hydrogen and carbonic acid gases are also disengaged; and in the retort there remains charcoal, mixed with lime and phosphate of lime.

Respecting the varieties of vegetable mucilage, which appear to be pretty numerous and well marked, much valuable information may be obtained from the paper of Dr. Bostock already quoted.

SECTION III.

Vegetable Jelly.

Vegetable jelly may be obtained from the recently expressed juices of certain fruits, such as the currant and gooseberry. When the expressed juice of these fruits is allowed to remain, for some time, in a state of rest, it partly coagulates into a tremulous soft substance, well known by the name of jelly. The coagulum, washed with a very small quantity of water is jelly nearly in a state of purity.

Vegetable jelly, unless when tinged by the colour of the fruit, is nearly colourless; has a pleasant taste, and a tremulous consistency. It is scarcely soluble in cold water; but very readily in hot, and the solution again gelatinates on cooling. By long boiling it loses this last property, and is changed into a substance analogous to mucilage. When dried it is transparent. It combines readily with alkalies. Nitric acid converts it into oxalic acid, without disengaging any azotic gas. Its solution in water is precipitated by infusion of galls.

SECTION IV.

Sugar and Oxalic Acid.

Art. I.—*Sugar.*

1. Sugar is soluble in an equal weight of cold water, and almost to an unlimited amount in hot water. The latter solution affords a liquid called syrup ; from which, by long repose, crystals of sugar separate.

2. Alcohol dissolves, when heated, about one-fourth its weight of sugar.

3. Lime-water renders sugar more soluble. Alkalies unite with it, and destroy its taste. It may be recovered, however, unchanged, by adding sulphuric acid, and precipitating the sulphate by alcohol, which retains the sugar in solution.

4. Sugar has the property of rendering oils miscible with water.

5. The sulphurets, hydro-sulphurets, and phosphurets, appear to have the property of converting sugar into a substance not unlike gum. (Thomson's Chemistry, iv. 214.)

6. It is converted, by destructive distillation, into acetous acid, carburetted hydrogen, and carbonic acid gas, and charcoal. According to Lavoisier, it is composed of 64 oxygen, 28 carbon, and 8 hydrogen.

Art. II.—*Oxalic Acid.*

Sugar is acidified by distillation with nitric acid. 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 (amounting to 58 parts from 100 of sugar), which must be again dissolved in water and crystallized. Lay this second crop of crystals on blotting-paper to dry.

The crystals of oxalic acid have the following characters:

1. They have a strong acid taste, and act powerfully on vegetable blue colours.

2. They dissolve in twice their weight of cold, and in an equal weight of hot water.

3. They effloresce in the air, and become covered with a white powder.

4. A red heat entirely decomposes them, and leaves only charcoal.

5. Oxalic acid combines with alkalies and earths, forming with the first soluble, and with the latter generally insoluble, compounds. The oxalate of potash may exist in two states, either exactly saturated, or with an excess of acid. The alkaline oxalates, as well as the uncombined acid, have the property of decomposing salts with base of lime; and hence are excellent tests of that earth.—Oxalate of ammonia, added to a solution of pure lime, or of any of its salts, immediately effects a precipitation of oxalate of lime.

SECTION V.

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.

Art. i.—*Citric Acid.*

Citric acid exists, nearly in an uncombined state, in the expressed juice of the lime and lemon, which contains also extractive matter and mucilage. The process, for obtaining it in a separate state, we owe to the ingenuity of Scheele. To the juice of the lime or lemon, contained in a vessel of earthen ware, or white wood, add, very gradually, finely powdered carbonate of lime (chalk or whiting), and stir the mixture well after each addition. An effervescence will ensue; and, as long as this arises, on adding fresh portions of chalk, more will be required. The exact proportion it is impossible to assign, on account of the variable strength of the acid juice. In general, from six to eight ounces of chalk are sufficient to saturate a wine-gallon of lime-juice. When it ceases to excite effervescence, and the liquor has lost its sour taste, leave the mixture to settle; decant the liquid, and add a quantity of water. Let the powder subside; the liquor be again decanted, and thrown away; and these operations repeated, till the water comes off nearly colourless. The insoluble precipitate consists of citric acid united with lime; add to it a quantity of sulphuric acid, of the density 1.8 equal to about 3-4ths the weight of the chalk which has been employed, and previously diluted with 20 parts of water; or the sulphuric acid may be poured, undiluted, upon the precipitate, suspended by stirring it in a considerable quantity of water.—Let the acid and precipitate remain together 24 hours; during which time they must be frequently stirred. Then let the white sediment, which consists of sulphate of lime, subside; decant the clear liquor; add more water till it comes off tasteless; and mix all the liquors together. The solution, containing citric and sulphuric acids, and some mucilage, is to be evaporated in shallow earthen dishes, placed in a sand-heat. Reduce the liquid about 3-4ths its bulk by evaporation; separate the sulphate of lime, which will be deposited, and again waste the liquor, by a heat not above 212°, to the consistence of syrup.—Dark brown crystals will form on cooling, which must be set to drain; and the remaining liquor, when again evaporated repeatedly, will continue to yield fresh crystals. To purify these, let them be dissolved in water; and the solution again evaporated. After the second crystallization, their colour will be improved; but it will require three or four crystallizations to obtain them perfectly white and well formed. In this state they are the pure citric acid.

The crystals of citric acid are readily soluble in water, one part of which at 60° takes up 1¼ its weight. They effloresce in the air: and with the alkalies and earths this solution unites and forms citrates.

ART. II.—*Gallic Acid.* [See Note 33.]

This acid exists in the gall-nut, along with tan and other substances. In Mr. Davy's experiments, 400 grains of a saturated infusion of galls, gave 53 of solid matter, composed of 9-10ths tan and 1-10th gallic acid. The acid 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 crystals must be dissolved in alcohol, to separate them from other substances, and the solution evaporated to dryness.

It may also be procured 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 may 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 *Tan*. From the remaining solution the superabundant oxide 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 two 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.

By none of these processes, however, can gallic acid be obtained perfectly pure; for it still, according to Mr. Davy, is contaminated with a small portion of extract.—To purify it, Deyeux advises its sublimation. Over a glass capsule, containing the impure acid, and placed in a sand-heat, another capsule is to be inverted, and kept cool.—On the impression of the heat, the acid rises into the upper one, in the form of white needle-shaped crystals.

The pure acid has the following characters:

1. Gallic acid burns with flame, when placed on a red-hot iron, and emits an aromatic smell.

2. It is soluble in 24 parts of cold, or 3 of boiling water. Alcohol, when cold, dissolves 1-4th, or an equal weight when heated.

3. The solution reddens blue vegetable colours.

4. Nitric acid converts the gallic into oxalic acid.

5. It precipitates most metals from their solutions; gold, silver, and copper, of a brown colour; lead, white; mercury, orange; bismuth, yellow; and iron, deep black. [See Note 34.] The precipitate from solutions of iron is soluble in an excess of

acid. It forms the basis of ink, which, according to Deyeux, consists of carburetted oxide of iron, and gallate of iron.

A full and valuable history of the gallic acid, and the process for obtaining it, by Bouillon La Grange, may be consulted in Nicholson's Journ. xvii. 58.

ART. III.—*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 other acids. 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. Or the juice of apples may be saturated with carbonate of potash, and mixed with a solution of acetate of lead, till the precipitate ceases. This precipitate is to be washed with water, and dilute sulphuric acid is to be added, till the liquor acquires an acid taste, unmixed with any sweetness. The liquor is to be filtered, to separate the sulphate of lead, and evaporated. It yields no crystals, but a thick liquor of a cherry-red colour.

The malic acid, in general, forms deliquescent salts.

ART. IV.—*Tartarous 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 alkalies. 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, or super-tartrite of potash. By adding to this as much alkali as will saturate the excess of acid, it becomes easily soluble; and, by again rendering the acid superabundant, it is again rendered insoluble.

ART. V.—*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.

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

ART. VII. Mr. Klaproth has lately discovered a new acid, combined with lime and extract, in a saline mass, which exudes from the trunk of the white mulberry, *morus alba*, L. It was collected, by Dr. Thomson, from trees in the botanic garden at Palermo; and seems peculiar to those individuals that grow in hot climates. Its characters have not been fully ascertained. From its origin, it has been called, by Klaproth, moroxylic acid, and its compounds moroxylates. (See Nich. Journ. 8vo. vii. 129.)

ART. VIII. The laccic acid (which, in strictness, should be classed among animal acids) is obtained from the white lac of Madras, from which, when liquefied, it oozes out in drops. It is in the form of a reddish liquor, having a slightly bitter saltish taste; but, on evaporation, it shoots into acicular crystals. It may be raised in distillation. It combines with carbonate of lime and soda, and excites effervescence. It precipitates barytic salts; assumes a green colour with lime-water, and a purplish one with sulphate of iron. A full account of its properties, and of those of the substance that affords it, may be found in Dr. Pearson's paper in the Phil. Trans. 1794.

SECTION VI.

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 are usually coloured, but may be deprived of colour by digestion with charcoal.

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

5. They unite with alkalies, and form soap.

Soap is readily soluble in water. The solution is decomposed by acids, and by neutral salts with earthy bases. Hence hard waters, which contain earthy salts, curdle soap; their acid uniting with the alkali of the soap, and setting the oil at liberty.

When a strong solution of soap is mixed with one of a metallic salt, a substance is formed, termed a metallic soap. The alkali unites with the acid of the salt, and the oil with the metallic oxide.

6. Fixed oils dissolve sulphur, and form a kind of balsam. They act also on phosphorus.

7. Their properties are changed by boiling with metallic oxides, those of lead for example. The mucilage unites with the oxide, 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. If the oxide be added in larger proportion, the mass, when cold, is a plaster.

8. Fixed oils are highly combustible. When distilled with a gentle heat, they yield olefiant and carburetted hydrogen gases.

SECTION VII.

Volatile, or Essential Oils.

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

2. They are volatilized by a gentle heat. Hence the spot which they leave on paper may be removed by the application of heat, while the stains from expressed oils are permanent.

3. They can, with difficulty, be brought to unite with alkalies.

4. They are soluble in alcohol.

5. They do not unite with water. With the intervention of a little sugar, however, they are combinable, in small proportion, with water.

6. 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.

7. Several of them detonate, when rubbed with hyper-oxygenized muriate of potash, and take fire when poured into oxygenized muriatic acid gas.

8. 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.

For this purpose, camphor is repeatedly distilled with four times it weight of nitric acid, till about 20 parts of acid have been employed. At each operation, the portion of camphor, which sublimes and escapes decomposition, is to be returned into the retort. The acid is susceptible of crystallization; the crystals effloresce in the air, and are sparingly soluble in water; they are combustible; and burn with a dense, aromatic smoke; they melt and sublime with a gentle heat, and dissolve in the mineral acids. They dissolve also in alcohol, and are not precipitated by water. With alkalies and earths they compose a class of salts called Camphorates.

SECTION VIII.

Resins.

Resins are inspissated juices of certain plants, and are generally obtained by wounding their bark. Copal, or lac, may be taken as an example. Dragon's blood, guaiacum, sandarach, labdanum, common resin, and turpentine, are also varieties of this substance.

1. They have generally a yellow colour, and are imperfectly transparent.
2. They are dry, brittle, and extremely inflammable.
3. They dissolve in alcohol, ether, and essential oils; but not at all in water, which even precipitates them from the foregoing solvents.
4. Both acids and alkalies act on them; the pure alkalies most remarkably.
5. They are the bases of varnishes, and are much used in medicine.

Gum-Resins, along with resin, have an admixture of extractive matter. They dissolve partly in water, and partly in alcohol. They are almost solely used in medicine. Asafœtida, gum-ammoniac, aloes, gamboge, myrrh, opium, &c. are varieties of gum-resin.

Amber is a resin possessed of peculiar properties. By distillation it yields a distinct acid, called the *succinic.* To prepare this acid, let a glass retort be half filled with powdered amber, and the remainder with fine dry sand. Lute a receiver, and apply a gentle heat. A portion of water first comes over, which is succeeded by a weak acetic acid. The succinic acid then sublimes; but is contaminated by a mixture of oil. It may be purified by solution and crystallization; and it then forms transparent white shining crystals, having the form of triangular prisms. They are soluble in 24 times their weight of water, and in boiling alcohol. The solution reddens the blue colour of turnsole, but not that of violets, and has an acid taste. It combines with alkalies, &c. and forms succinates.

SECTION IX.

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. Farina is insoluble in alcohol.

3. Pure liquid alkalies act on starch; and convert it into a transparent jelly. The compound is soluble in alcohol.

4. Sulphuric acid dissolves it slowly; sulphurous acid is evolved; and so much charcoal is disengaged, that the vessel may be inverted, without spilling its contents.

5. Nitric acid, at the temperature of the atmosphere, acts on starch, and dissolves it; but no oxalic acid appears subsequently, unless heat be applied. Hot nitric acid is decomposed by starch, and oxalic acid is generated.

6. Starch, as it exists in grain, is convertible into sugar. On this property is founded the process of malting.

7. Starch is capable of entering into chemical union with tan. (Thomson, in Nicholson, ix. 74.)

8. When distilled alone, it yields an acid, termed the pyromucous. This has been lately shown to be identical with vinegar.

9. Farina forms a considerable part of wheat and other flour, and of the potatoe. It may be obtained separate by washing with water.

10. It becomes sour when exposed in a moist state to the air.

SECTION X.

Gluten.

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.

The following are the properties of gluten:

1. It is of a grey colour, and has so much elasticity, that, when drawn out, it recovers itself like elastic gum. It has scarcely any taste, and does not lose its tenacity in the mouth.

2. When exposed to a gentle heat, it dries very slowly, and becomes hard, brittle, semi-transparent, of a dark-brown colour, and somewhat like glue. When broken it has the fracture of glass. In this state it is insoluble in water.

3. When kept moist, it ferments and undergoes a sort of putrefaction, emitting a very offensive odour.

4. When suddenly heated, it swells prodigiously; then melts, blackens, and yields a smell like that of burning horn.

5. It is insoluble in water*, in alcohol, and in ether; but, after fermentation, it is partially soluble in alcohol, and the solution may be applied to the purposes of varnish.

6. All acids dissolve it, and alkalies precipitate it, but considerably changed, and deprived of its elasticity. It undergoes a similar change when dissolved in pure alkalies, and precipitated by acids.

7. It exists most abundantly in wheat-flour; and is essential to its soundness; but it is found, also, in various vegetable juices; (see Proust on the Green Fecula of Vegetables, Nich. Journ. 8vo. iv. 273.)

SECTION XI.

Caoutchouc, or Elastic Gum.

1. Caoutchouc is inflammable, burning with a bright flame in atmospherical air, and with still greater brilliancy in oxygen gas, or in oxygenized muriatic gas.

2. It is insoluble in water and in alcohol. If long slips of caoutchouc, however, are tied spirally round a glass or metal rod, and boiled for an hour or two, the edges cohere, and a hollow tube is formed.

3. Caoutchouc is soluble in ether; not, however, in the ordinary state of this fluid as it is found in the shops. To render ether a fit solvent of this substance, it should be purified by washing it with water, in the manner to be hereafter described. The solution may be applied to the purpose of forming tubes or vessels of any shape.

4. Caoutchouc is soluble in volatile oils; but when they have evaporated, they leave it in a glutinous state, and deprived of

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* From the recent experiments of Dr. Bostock, gluten appears, by long digestion, to be partly soluble in water. The solution is precipitated by acetate and super-acetate of lead, by muriate of tin, and by other re-agents. (Nich. Journ. xviii. 34.)

much of its elasticity. Petroleum dissolves it, and, when evaporated, leaves it unchanged.

5. It is acted on by alkalies; and, when steeped in them for some time, loses its elasticity.

6. The sulphuric acid is decomposed by it; sulphurous acid is disengaged; and charcoal remains. Nitric acid acts on it with the assistance of heat, nitrous gas is formed; and oxalic acid crystallizes from the residuum.

7 When distilled it gives ammonia, and hence may be inferred to contain azote.

SECTION XII.

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. The pure fixed alkalies act on the woody fibre, and render it soft, and of a brown colour.

4. Nitric acid decomposes it with the assistance of heat: and oxalic, citric, malic, and acetic acids, are formed.

5. When exposed to heat, it affords an acid called the *pyroligneous*, which has been lately proved to be identical with the acetous. In the retort a black substance remains, which is charcoal.

SECTION XIII.

Colouring Matter.

I. The colouring matter of vegetables presents a considerable variety in its relation to chemical agents, depending on the diversity of the basis, or sub-stratum, in which it resides. Chaptal has arranged the varieties of the colouring principle under four heads. 1st, As it is attached to extractive matter: 2d, As it resides in gum; in both which cases it is soluble in water: 3d, As it exists in farina, or fecula; and in this instance it dissolves most readily in sulphuric acid: 4th, The colouring principle is occasionally inherent in resin, and then it requires alcohol, an oil, or an alkali, for solution.

II. The extraction of colouring matter from the various substances that afford it, and its fixation on wool, silk, or cotton, constitute the art of dyeing; the details of which would be foreign to the purpose of this work. In this place I shall state only a few general principles; and refer for more minute information to the works of Berthollet and Bancroft.

III. Of the various colouring substances, used in the art of dying, some may be permanently attached to the dyed fabric, and fully communicate their colour to it, without the intervention of any other substance; while others leave a mere stain, removeable by washing with water. The latter class, however, may be durably attached by the mediation of a proper *basis*. The colours, which are of themselves permanent have been termed, by Dr. Bancroft, *substantive* colours; while those that require a basis, have been denominated *adjective* colours.

IV. The most important bases, by the mediation of which colouring matter is united with wool or cotton, are alumine, the oxide of iron, and the oxide of tin.—Alumine and oxide of iron are applied in combination with sulphuric, or acetic acids; and the oxide of tin, united with nitro-muriatic, muriatic, acetic, or tartarous acids. In dyeing, the most common method is to pass the substance to be dyed through a decoction of the colouring matter, and afterwards through a solution of the basis.—The colouring principle thus becomes permanently fixed on the cloth, sometimes considerably changed by its union with the basis. In calico-printing, the basis, thickened with gum or flour paste, is applied to the cloth by wooden blocks, or copper cylinders. The cloth is then dried, and passed through a decoction of the colouring ingredient, which adheres only to that part of the cloth where the basis has been applied. From the rest of the cloth it is removed by simple washing with water.

V. The variety of colours, observed in dyed substances, are reducible to four simple ones, viz. blue, red, yellow, and black.

1. Indigo is the only substance used in dyeing blue, which it does without the intervention of a basis. In its ordinary state it is insoluble in water, and in any other solvent except sulphuric acid. When thus dissolved, it is sometimes applied directly, in a diluted state, to the fabric, and dyes what is termed a Saxon blue. But, by the abstraction of part of its oxygen, indigo becomes soluble; and its colour changes from blue to green. It recovers the former colour, however, on exposure to the air, by again absorbing oxygen. Its de-oxydizement is effected by allowing it to ferment, along with bran, or other vegetable matter; or by decomposing, in contact with it, the green sulphate of iron. Substances dyed by indigo, thus deprived of oxygen, are green, and acquire a blue colour by exposure to the atmos-

phere. By this revival, the indigo again becomes insoluble, and fitted, therefore, for affording a permanent dye.

2. The substances, chiefly employed for affording red colours, are cochineal (an insect which has been supposed to derive colour from its food, the leaves of the *cactus opuntia*, L.), archil, madder, brazil-wood, and saf-flower. The first four are soluble in water; the last not without the intervention of an alkali. They are all adjective colours. Cochineal, though its colour is naturally crimson, is used for dyeing scarlet; and to evolve the scarlet hue, it is necessary to employ the supertartrite of potash. The basis, by which it is attached to cloth, is the oxide of tin. This may be exhibited experimentally. A decoction of cochineal will leave only a fugitive stain on a piece of cloth; but if, in the decoction, some supertartrite of potash has been dissolved, and a portion of nitro-muriate of tin afterwards been added, it will impart a permanent scarlet colour.

3. The yellow dyes are wild American hiccory, sumach, turmeric, fustic, and quercitron bark; which afford various colours, accordingly as they are combined with the cloth, by the intervention of alumine, or of oxide of iron, or tin. Thus, with the aluminous base, the quercitron bark yields a bright yellow; with oxide of tin, all the shades, from pale-lemon colour to a deep orange; and with oxide of iron, a drab colour. With the addition of indigo, it gives a green.

4. A combination of red oxide of iron, with the gallic acid and tan, is the principal black colour, which has therefore the same basis as common writing-ink. In calico-printing, white spots, or figures, on a black ground, are produced, by previously printing on the cloth a protecting paste of citric acid, thickened with gum or flour. The parts to which this paste is applied, do not receive the black dye, but remain perfectly white.

VI. The colouring matter of vegetables, besides being capable of fixation on cloth, may be obtained combined with a base. Thus if to a decoction, or infusion, of madder in water, a solution of sulphate of alumine be added, the colouring matter is precipitated in combination with the alumine, forming what is termed a *lake*. For obtaining this, the following process is given by Sir H. Englefield. Put two ounces of Dutch crop madder into a calico bag, capable of holding three or four times that quantity. Pour on it a pint of distilled water, and triturate, in a mortar, as much as can be done, without destroying the bag. The water becomes loaded with colouring matter, and is opake and muddy. Pour off this portion, and repeat the operation till no more colour is obtained, which will generally happen after the fifth or sixth affusion.—Pour these several washings into an earthen or well-tinned copper pan; and apply heat till the liquor boils.—Let it then be poured into a basin; and one ounce of alum, dissolved in a pint of water, be added, and mixed by stirring. Add an ounce and a half of saturated solution of sub-carbonate of potash; a violent effervescence will ensue, and the colouring matter will be precipitated. Stir the mixture till cold, and wash repeatedly with boiling water. About half an ounce of lake will be obtained, containing 2-5ths its weight of alumine.

Other lakes may be obtained, of different colours, by the substitution of different dyeing woods; and from the infusion of cochineal, the beautiful pigment called Carmine is precipitated by means of a solution of tin.

SECTION XIV.

Tan, Tannin, or the Tanning Principle.

Tan exists abundantly in the bark of the oak, the willow, &c. and in the gall-nut. The interior bark, next to the wood, contains the largest proportion; the middle and coloured part, the next; and in this it is accompanied with more extract. The epidermis affords very little.

I. Tan may be obtained by any of the following processes; but, according to Mr. Davy, it is difficult to procure it in a state of perfect purity.

1. 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 oxide of tin is precipitated by a stream of sulphuretted hydrogen gas; and the tannin, which remains dissolved, may be procured by evaporation.

2. 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. When thus prepared, Mr. Davy observes, that tan is not perfectly pure, but contains a minute proportion of gallic acid and alkali.

3. Into a similar infusion, pour sulphuric or muriatic acid. A precipitate will form, which must be re-dissolved in water, and the excess of sulphuric acid saturated by carbonate of potash. When a farther addition is made of the alkali, the tan falls down, and must be purified by washing with a small quantity of water.

It has been discovered by Mr. Davy, that the terra japonica, or catechu (which is to be met with under this name in the druggists' shops), is composed of about one half tan, the remainder being a mixture of extract, mucilage, and earthy impurities.

II. 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 water, but still more readily in alcohol.

2. From this watery solution all acids precipitate tan.

3. The alkaline carbonates have a similar effect.

4. The watery solution, poured into one of glue (inspissated animal jelly), converts it immediately into a coagulum, insoluble by boiling water, which has the elastic properties of the gluten of wheat.

The solution of gelatine, or jelly, may be prepared, for the purpose of precipitating tan, by dissolving isinglass in water, in the proportion of ten grains to two ounces. The precipitate consists of 54 jelly and 46 tan*. An excess of the solution partly re-dissolves it. It is this property, of forming with gelatine an insoluble compound, that fits tan for the purpose of preserving leather.

5. Tan forms, with fecula, or starch, a precipitate, which is sparingly soluble in cold water, and very copiously in hot water.

6. With gluten it gives an insoluble precipitate.

7. It is precipitated by salts with earthy bases, such as the nitrates of barytes, lime, &c.

8. It is separated also by salts with metallic bases, such as acetate of lead, muriate of tin, muriate of gold, and sulphate of iron.

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* From conversation with Dr. Duncan, jun., who has made numerous experiments on tan, I learn, that the proportion of ingredients in this precipitate varies very considerably, according to the mode in which it is effected; and that insolubility in water is by no means one of its constant characters. In ammonia it dissolves readily.

Green sulphate of iron effects no change in the solution of tan, but the red sulphate occasions a dark-bluecish precipitate. This precipitate differs from gallate of iron, in being decomposed by acids, the tan being thus separated. An excess of the red sulphate re-dissolves the precipitate, and affords a black or dark-blue liquor. By union with tan, the red sulphate is de-oxydized, 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.

Until very lately, tan had been known only as a production of nature; and the processes of chemistry had effected nothing more, than its separation from the various substances, with which it occurs combined. An important discovery, however, has been very recently made by Mr. Hatchett, of the artificial formation of tan, from substances which unquestionably do not contain it, but only furnish its elements. The processes for its factitious production are very numerous; but they are arranged, by their author, under three heads. 1st, The synthesis of tan may be effected by the action of nitric acid on animal or vegetable charcoal; 2dly, By distilling nitric acid from common resin, indigo, dragon's blood, and various other resinous substances; 3dly, By the action of sulphuric acid on common resin, elemi, assafœtida, camphor, &c. Of these various processes, I shall select the most simple, referring to Mr. Hatchett's very interesting paper for a fuller detail of the experiments. (See Phil. Trans. for 1805 and 1806.)

To 100 grains of powdered charcoal, contained in a mattras, add an ounce of nitric acid (specific gr. 1.4) diluted with two ounces of water; place the vessel in a sand-heat, and continue the digestion till the charcoal appears to be dissolved. A copious discharge of nitrous gas will take place. At the end of the second day, it may be necessary to add another ounce, and sometimes even a third, of nitric acid; and to continue the digestion during five or six days. A reddish-brown solution will be obtained, which must be evaporated to dryness in a glass vessel; taking care, in the latter part of the process, so to regulate the temperature, that the acid may be expelled, without decomposing the residuum. A brown glossy substance will be obtained, having a resinous fracture, and amounting, in weight, to 116 or 120 grains. This substance has the following properties:

1. It is speedily dissolved by cold water and by alcohol. 2. It has an astringent flavour. 3. Exposed to heat, it smokes but

little, swells much, and affords a bulky coal. 4. Its solution in water reddens litmus paper. 5. The solution copiously precipitates metallic salts, especially muriate of tin, acetate of lead, and red sulphate of iron. These precipitates, for the most part, are brown, inclining to chocolate, excepting that of tin, which is blackish grey. 6. Gold is precipitated from its solution in a metallic state. 7. The earthy salts are precipitated by it. 8. Gelatine is instantly precipitated from water, in the state of a coagulum, insoluble both in cold and in boiling water.

The identity of this substance with tan can, therefore, be scarcely doubted, since the two bodies agree in having the same characteristic properties. The only essential circumstance of discrimination, is, that the natural tan is destroyed, while the artificial is produced, by the agency of nitric acid; and that the artificial substance, even when formed, powerfully resists the decomposing action of this acid, which readily destroys natural tan. Even, however, among the different varieties of the natural substance, Mr. Hatchett found essential differences in the facility of destruction by nitric acid. Those of oak bark and catechu are least destructible; and, in general, the varieties of tan seem to be least permanent, in proportion to the quantity of mucilage which they contain. Infusions of factitious tan differ, also, from those of the natural kind, in not becoming mouldy by keeping.

The artificial substance is a purer variety of tan than the natural one; inasmuch as it is perfectly free from gallic acid, and from extract, both of which are always present in the latter. The properties of the factitious compound vary a little, according to the mode of its preparation, principally in the colour of the precipitates, which they separate from metallic solutions. Those effected by tan, formed by processes of the first class, are always brown, and by the second, pale or deep yellow.

SECTION XV.

Wax.

Wax appears to be the product of vegetables, and not an animalized substance; for it exists in the fecula of houseleek, in lac, and exudes from a tree called Myrica Cerifera.

1. Wax is readily fusible and inflammable; and may be volatilized in close vessels.

2. It is insoluble in water.

3. Boiling alcohol dissolves a considerable proportion, which separates, in a great measure, on cooling; and the solution is immediately precipitated by the addition of water. Boiling ether dissolves about 1-20th of its weight.

4. Caustic fixed alkalies convert it into a saponaceous compound, soluble in warm water. A heated solution of ammonia dissolves it, and forms a kind of emulsion. On cooling, the wax rises to the surface in flocculi.

5. When distilled alone with a gentle heat, olefiant and hydrocarburet gases are obtained.

SECTION XVI.

The Bitter Principle.

The bitter taste of certain vegetables appears to be owing to the presence of a peculiar substance, differing from every other in its chemical properties. It may be extracted from the wood of quassia, the root of gentian, the leaves of the hop, and several other plants, by infusing them for some time in cold water. The characters of this substance, originally described by Welther, have been attentively examined by Dr. Thomson, who enumerates them as follows. (Chemistry, v. 95.)

1. When water, thus impregnated, is evaporated to dryness by a very gentle heat, it leaves a brownish yellow substance, which retains a certain degree of transparency. For some time it continues a ductile, but at last becomes brittle. Its taste is intensely bitter.

2. When heated, it softens, swells, and blackens; then burns away without flaming much; and leaves a small quantity of ashes.

3. It is very soluble in water, and in alcohol.

4. It does not affect blue vegetable colours.

5. It is not precipitated by the watery solution of lime, barytes, or strontites; nor is it changed by alkalies.

6. Tincture of galls, infusion of nut-galls, and gallic acid, produce no effect.

7. Of the metallic salts, nitrate of silver and acetate of lead are the only ones that throw it down. The precipitate by acetate of lead is very abundant; and that salt, therefore, affords the best test for discovering the bitter principle, when no other substances are present, by which, also, it is decomposed.

From recent experiments of Mr. Hatchett, it appears that the bitter principle is formed, along with tan, by the action of nitric acid on indigo.

SECTION XVII.

Narcotic Principle*.

Opium, and other vegetable products possessed of a narcotic power, are composed of several of the vegetable principles, that have already been enumerated. Besides these, however, they contain a peculiar one, in which the narcotic virtue resides.

I. To obtain the narcotic principle from opium, let water be digested upon it, and the strained solution be evaporated to the consistence of syrup. A gritty precipitate will begin to appear, which is considerably increased by diluting the liquid with water. This consists of three distinct substances, resin, oxygenized extract, and the narcotic principle. Boiling alcohol dissolves the resin and narcotic principle only; and the latter falls down in crystals, as the solution cools; still, however, coloured with resin. The crystals may be purified by repeated solutions and crystallizations.

II. 1. The narcotic principle, thus obtained, is white. It crystallizes in rectangular prisms with rhomboidal bases. It is destitute of taste and smell.

2. It is insoluble in cold water, but is soluble in 400 parts of boiling water, from which it precipitates again as the solution cools. When thus dissolved, it does not affect vegetable blue colours.

3. It is soluble in 24 parts of boiling alcohol, and in 100 of cold alcohol. Water precipitates it, in the state of a white powder.

4. Hot ether dissolves, but deposits it on cooling. When heated in a spoon, it melts like wax.

5. It is soluble in acids, and precipitated by alkalies. With nitric acid it dissolves, and becomes red; and much oxalic acid is formed, a bitter substance remaining.

6. It may be combined with water and alcohol, by the intervention of resin and extract, the presence of which seems originally to render it soluble in those fluids.

SECTION XVIII.

Suber, and its Acid.

This name is used to denote common cork wood, which appears to be possessed of peculiar properties, especially in its relation to nitric acid.

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* I cannot find, from conversation with various chemical friends, that the narcotic principle has been obtained separate in this country.

I. To a quantity of cork, grated into powder, and contained in a tubulated retort, add six times its weight of nitric acid, of the specific gravity 1.261; and distil the mixture, with a gentle heat, as long as any red vapours escape. As the distillation advances, a yellow matter, like wax, appears on the surface of the liquid. While the contents of the retort continue hot, they are to be poured into a glass vessel, placed on a sand bath, and constantly stirred with a glass-rod, by which means the liquid gradually becomes thick. As soon as white penetrating vapours appear, let it be removed from the sand bath, and stirred till it becomes cold. An orange-coloured mass will be obtained, of the consistence of honey, having a strong and sharp odour while hot, and a peculiar aromatic smell when cold. On this, pour twice its weight of boiling water; apply heat till it liquefies; and filter. The filtered liquor, as it cools, deposits a powdery sediment, and becomes covered with a thin pellicle. The sediment is to be separated by filtration; and the liquid reduced, by evaporation, nearly to dryness. This mass is the suberic acid. It may be purified, either by saturating it with alkali, and precipitating by an acid, or by boiling it with charcoal powder.

II. Suberic acid has the following properties:

1. It is not crystallizable.

2. It has an acid and slightly bitter taste; and, when dissolved in boiling water, it acts on the throat, and excites coughing.

3. It reddens vegetable blues, and changes the blue solution of indigo in sulphuric acid to green.

4. Cold water dissolves about 1-150th its weight, and boiling water half its weight.

5. It attracts moisture from the air.

6. When heated in a mattras, it sublimes, and is obtained in concentric circles, composed of numerous small points.

7. With alkalies, earths, and metallic oxides, it forms a class of salts called Suberates.

CHAPTER XX.

RESULT OF THE SPONTANEOUS DECOMPOSITION OF VEGETABLE SUBSTANCES.

SECTION I.

Vinous Fermentation.

THE phenomena and results of this process should be accurately examined, by means of an apparatus similar to that described in Lavoisier's Elements, part iii. ch. vi. A more simple one, however, will sufficiently answer the purpose. It may consist of a large glass mattras, shaped like that (fig. 4.), capable of holding 10 or 12 pints. Into the opening of the neck, a glass tube may be cemented, which is twice bent at right angles. The aperture of the other leg may terminate in a two-necked bottle, from which a bent glass tube is to proceed, and to be carried under the shelf of the pneumatic trough, or (which is better) into the receiving-pipe of a gazometer, fig. 35. *b*. The mattras may then be half filled with a solution of sugar in a proper quantity of water, or with an infusion of malt, with the addition of a little yeast. When placed in a room, the temperature of which is not below 60° Fahrenheit, the fermentation soon begins to take place ; a brisk motion is observed in the liquid ; it becomes turbid, and deposits some impurities, while a frothy scum rises to the surface. When the materials are in large quantity, viz. sufficient to fill a cask, a hissing noise is heard in the liquid, and its bulk increases so much, that, if the vessel were full, it now overflows. At the same time, a considerable quantity of gas escapes, and passes, through the bent tube, into the receiver inverted in the pneumatic trough, or into the gazometer. During the process of fermentation, the liquor preserves a higher temperature than that of the surrounding atmosphere. After some days, these appearances gradually decline ; and, if the process has been well conducted, and suspended at the proper period, the result is a liquor, not sweet, like that submitted to experiment, but having a vinous taste and smell.

When the gas, contained in the gazometer, is examined, it is found to be carbonic acid, holding in solution something which has a smell like that of the fermented liquor. On submitting the latter to distillation, we obtain a liquid considerably lighter than water, and having a strong spirituous taste. This, when deprived of the water with which it is combined, is alcohol.

SECTION II.

Alcohol.

I. To prepare alcohol, the spirit of wine of the shops may be employed. To a quantity contained in a glass vessel, the subcarbonate of potash, perfectly dry, is to be added ; the mixture is to be well shaken ; the clear liquor decanted ; and this is to be repeated as long as the alkali is moistened by the spirit. When enough has been employed, the next addition will fall to the bottom in a perfectly dry state. The dry muriate of lime may be advantageously used as a substitute for alkali. The clear liquid is next to be distilled by the heat of a water-bath; and the result is pure alcohol.

II. 1. Alcohol is considerably lighter than water, viz. in the proportion of 800 or 820 to 1000. The spirit of wine of the shops, however, containing much water, has the specific gravity of 835 or 840. The quantity of alcohol in mixtures of that fluid with water, of almost every degree of specific gravity, may be learned from Mr. Gilpin's copious Tables*.

2. Alcohol unites chemically with water; and caloric is evolved during this union. Equal measures of alcohol and water, each at 50° Faht, give by admixture an elevation of nearly 20° of temperature; and equal measures of proof-spirit and water an increase of $9\frac{1}{2}$°. The bulk of the resulting liquid is less also than that of the two before admixture.—Thus a pint of alcohol and a pint of water, when the mixture has cooled to the temperature of the atmosphere, falls considerably short of two pints.

3. Alcohol is highly inflammable. During its combustion, carbonic acid is generated; and a quantity of water is produced which exceeds in weight the alcohol employed An ingenious apparatus, for the purpose of ascertaining this fact, is described in the third part of Lavoisier's Elements, and is represented in the 9th plate to that work, fig. 5. The flame of alcohol acquires a red colour from muriate of lime, and a deep blood-red from the muriate of strontites.

4. Alcohol boils at 176°, and is converted into a gas, which may be exploded by passing an electric spark through a mixture of it with oxygen gas.

5. It has never yet been congealed by any degree of artificial cold.

6. By transmission through an ignited porcelain tube, alcohol yields olefiant and hydro-carburet gases, with a small proportion of carbonic acid gas. A portion of fine light sooty charcoal remains in the tube.

7. Alcohol is a powerful solvent. It dissolves soap; vegetable extract; sugar; acidulous tartrite of potash; oxalic, cam-

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* Phil. Trans. 1794; or an abstract in Nich. Journ. 4to. vol. i. See also the Appendix.

phoric, and benzoic acids; volatile oils; resins; and balsams. It combines, also, with sulphur, phosphorus, and the pure alkalies.

By distillation with certain acids, alcohol forms ether.

SECTION III.

Ether.

I. To prepare *Sulphuric Ether*, pour into a retort any quantity of alcohol, and add, at intervals sufficient to allow the mixture to cool after each addition, an equal weight of concentrated sulphuric acid, agitating them together each time. Let the retort be placed in a sand bath previously heated, and be connected by means of an adopter, with a tubulated receiver. To the tubulure of the receiver, a glass tube, twice bent at right angles, may be luted; and its aperture be immersed in a cupful of water or mercury. The condensible vapour is thus confined; while the gases that are produced are allowed to escape. The receiver should be kept cool by the application of moistened cloths. As soon as the materials begin to boil, ether is produced, and passes over into the receiver. The ebullition is to be continued, till white vapours appear in the retort, or a smell of sulphurous acid is perceived; and the receiver is then to be removed. The liquor, which it contains, will probably have a smell of sulphurous acid. To purify it, a small quantity of black oxide of manganese may be added, and the mixture may be kept in a bottle about 24 hours, agitating it occasionally. The clear liquid is then to be decanted, and distilled in a water bath, till one half has come over. This is to be preserved in a well closed vial.

II. *Nitric ether* may be prepared as follows. To two pints of alcohol, contained in a glass retort, add, by degrees, half a pound of nitric acid; and, after each addition, cool the materials, by setting the retort in a vessel of cold water. Distil the mixture by a very cautiously regulated heat, till about a pint and a half have come over. In this state the ether is far from being pure, and must be re-distilled, with the addition of pure potash, preserving only the first half or three-fourths that come over.

Thenard prepared nitric ether by the following process. Into a retort, he put equal parts (about 16 oz. of each) of alcohol and nitric acid; and adapted to it in succession, by means of glass tubes, five tall bottles, half filled with a saturated solution of muriate of soda. In the last, was a bent tube, opening under a jar, to receive the gas. The bottles were surrounded by a mixture of pounded ice and salt, which was stirred occasionally.

To commence the operation, a little fire was applied, but it soon became necessary to extinguish it, and to cool the retort. On the surface of the saline solution, in each of the bottles, was found, after the process was concluded, a yellowish liquid, equal in weight to about half the alcohol employed. That in the first bottle was impure; but the remaining four contained nitric ether free from admixture.

Nitric ether, thus prepared, is specifically lighter than water, but heavier than alcohol. It dissolves in the latter fluid, but requires for solution 48 parts of water. It reddens litmus; and though this property may be destroyed by a little lime, yet the ether soon becomes acid again by keeping. It is highly combustible; and much more volatile than the best sulphuric ether. It is composed, in 100 parts, of 16 azote, 39 carbon, 34 oxygen and 9 hydrogen. (Nicholson, xviii. 144.)

III. To prepare *muriatic ether*, add, to a mixture of 8 parts of manganese and 24 of muriate of soda, in a retort, 12 parts of sulphuric acid, previously mixed, with the necessary caution, with 8 of alcohol, and proceed to distillation. The ether, thus obtained, requires to be rectified by a second distillation from potash; and is still liable to be contaminated with sulphuric ether. A more certain process, which is not, however, unaccompanied with some difficulty, consists in passing oxygenized muriatic gas through alcohol: and, according to Klaproth, this kind of ether may, also, be safely and effectually prepared by distilling equal parts of alcohol and oxygenized muriate of tin. The distilled liquid is to be rectified by a second distillation with caustic potash. An improved mode of preparing this ether, and an account of its properties, by Thenard, may be found in Nich. Journ. xviii. 177.

IV. Sulphuric ether will be best employed to exhibit the properties of this substance, which are the following:

1. It is extremely light, having the specific gravity, when quite pure, of 758.

2. It does not, like alcohol, combine with water; and when the two fluids are shaken together, they separate again on standing. Water, however, retains about 1-10th its weight of ether. By repeated agitation with water, ether is brought to a high degree of purity, and acquires the property of dissolving caoutchouc.

The process, as performed in his presence by Mr. Winch of London, is described by Faujas St. Fond as follows. Let a pint of good sulphuric ether be put into a bottle (or, in preference, into the separator, plate i. fig. 3.) along with two pints of water; agitate the two liquids repeatedly together; then let them stand till the ether has risen to the surface; and draw off the water through the lower cock *b*, leaving the ether in the vessel. Repeat this process three or four times, or till scarcely one-third of the ether remains; and decant the residue into a well stopped vial. In this ether the elastic gum, cut into thin slips, soon begins to swell; but its action is slow, and about the end of five days, the solution is completed. The method of forming tubes, &c. with this solution, is described in the first volume of Faujas's Travels in England, ch. i.

3. Ether is extremely volatile. A few drops, poured on the hand, evaporate instantly; and produce a sense of great cold. By pouring a small stream of ether, on a thermometer bulb filled with water, from a capillary tube, the water is frozen, even in a warm summer atmosphere.

4. A mixture of sulphuric and muriatic ethers evaporates instantaneously, and produces a degree of cold considerably below 0 of Fahrenheit.

5. Ether assumes a solid form, by reducing its temperature to—46° Fahrenheit.

6. Ether is converted into a gas, either by raising its temperature, or diminishing the pressure of the atmosphere on its surface. The experiments proving this have already been described, chap. iii. sect. 3.

7. Ether does not dissolve the fixed alkalies, but combines with ammonia.

8. It dissolves essential oils and resins.

9. It is highly inflammable. This is best shown by passing a few drops into a receiver furnished with a brass cap and cock, to which a small pipe is screwed, and inverted in water of the temperature of 100°. The receiver will be filled with the gas of ether, which may be expelled through the pipe and set on fire. It burns with a beautiful deep blue flame.

10. When ether is previously mixed with oxgen gas, it detonates loudly. Into a strong two-ounce vial, filled with oxygen gas, and wrapped round with a cloth, let fall a drop of ether. On applying the flame of a candle, a violent detonation will ensue. Or to a portion of oxygen gas, contained in the detonating tube, fig. 28. pass up a drop or two of ether. The volume of the gass will be much increased; and, on transmitting an elec-

tric spark, a violent detonation will ensue, which will probably shatter the tube. In an experiment of Mr. Cruickshank, 3 measures of oxygen and 1 of ethereal gas detonated most violently, and $2\frac{1}{3}$ measures of carbonic acid gas were produced.

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 a 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.

11. According to Mr. Cruickshank, the proportion of carbon to hydrogen is in alcohol as 8 or 9 to 1, and in ether as 5 to 1.

SECTION IV.

Acetous and Acetic Acids.

I. Acetous acid may be obtained, by exposing to the atmosphere, the fermented liquor from malt or sugar, in a temperature between 75° and 90° of Fahrenheit. The liquor becomes warm; a number of ropy filaments appear; and, after several days exposure, it acquires an acid taste and smell. Little or no gas is produced; but, on the contrary, the atmospheric oxygen is absorbed. To this change, exposure to the air or to oxygen gas is an indispensable condition; whereas the vinous fermentation may be performed in close vessels, or at least in vessels which only allow egress to the elastic fluids.

2. The vinegar thus obtained is far from being pure. It is contaminated with mucilage and extract, and may be purified from these by distillation, rejecting the first portions that come over. When thus distilled, it may be taken as an example of acetous acid.

Acetous acid may, also, be obtained by the distillation of wood, and various other vegetable substances, in iron vessels.

3. Acetous acid unites with alkalies, earths, and metallic oxides.

When potash, saturated with this acid, is evaporated to dryness, the salt assumes a black colour. On being re-dissolved, however, and again evaporated, the salt is obtained white, and, when fused and suffered to cool, affords the acetate 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 carburetted hydrogen gases 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, mixed with sulphurous acid. Digestion with a small portion of manganese, and subsequent distillation, affords it pure. It may be obtained, also, by distilling equal parts of acetate of lead and sulphate of copper.

The crystallized acetate of copper, contained in a glass retort, which may be nearly filled with the salt, is to be submitted to distillation in a sand-heat. The acid that comes over has a green colour, and requires to be rectified by a second distillation.

4. The acetic acid, in the temperature of 38° of Fahrenheit, congeals or becomes glacial, and again liquefies at 39°.

5. When distilled with alcohol, it affords an ether termed acetic ether. (See Thenard's Process, Nich. Journ. xviii. 185.)

The acetous acid may be also combined with oxides of lead and of copper. Lead corroded into a white oxide, or rather sub-acetate, by the fumes of vinegar, forms ceruse, or white-lead, which, when dissolved in distilled vinegar and crystallized, constitutes the acetate, 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 the experiments of 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 acid, merely by abstracting its water by muriate of lime, under circumstances where no farther oxygenation could take place. Both terms, however, may be retained for the sake of brevity of expression, the *acetous* denoting the dilute acid, as obtained by fermentation, &c.; and the acetic, the acid in its most concentrated state.

CHAPTER XXI.

ANIMAL SUBSTANCES.

SECTION I.

Animal Jelly, or Gelatine.

To exhibit the properties of gelatine, a solution of isinglass, in water, may be employed.

The distinguishing characters of gelatine, are,

1. Its solution in warm water concretes, on cooling, into a gelatinous mass; and this effect takes place when the real quantity of solid gelatine, in the solution, does not exceed 1-100th part its weight. (Bostock*.)

2. When the solution of gelatine is evaporated, it forms a tough semi-transparent mass, which may again be dissolved in water, and more readily with the aid of heat.

3. The solution of gelatine, exposed to the air, becomes sour, or undergoes the acetous fermentation.

4. It is precipitated by a solution of tan, in the form of a dense coagulum; which, when dry, has a vitreous fracture; is quite insoluble in water † and in alcohol; but recovers its elasticity if moistened with warm water.—This compound is the preservative part of tanned leather, to which it imparts the property of resisting the transmission of moisture. An infusion of tan detects gelatine, when the latter constitutes only 1-5000th the bulk of the solution. (Bostock.)

5. Gelatine is not precipitated by the super-acetate of lead, better known by the name of Goulard's extract (prepared by boiling litharge in distilled vinegar,) nor by a solution of corrosive muriate of mercury. It is slightly precipitated by nitrate of silver, and by muriate of gold, provided it is present in not less than 1 part to 50 of the solution. From Dr. Duncan, junior, I learn that gelatine is precipitated by sub-carbonate of potash.

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* Dr. Bostock's experiments on the characters of the primary animal fluids are contained in Nich. Journ. xi. 244. and xiv. 140.

† Some exceptions, however, have been stated under the article TAN.

6. Gelatine, when evaporated, forms the basis of portable soup, isinglass, glue*, &c. It may be extracted from all the soft parts of animals by boiling, and even from the bones. It constitutes the nutritious part of jellies, soups, &c.

SECTION II.

Albumen.

1. The white of an egg affords a good example of animal albumen; though it appears, from Dr. Bostock's experiments, not to be this substance in a perfectly pure state, but to contain, in 100 parts, 80 water, 15½ solid albumen, and 4½ uncoagulable matter, consisting of mucus.

2. The solution of albumen, which may be obtained by agitating the white of an egg with water, is coagulable by heat; and gives a manifest opacity, even when it composes only 1-1000th the weight of the solution. In its undiluted state, it is coagulated by a temperature of 160° into a solid mass, of a smooth homogeneous texture. This coagulum cannot be again dissolved in water, and is soluble only in fixed alkalies. During its solution in alkalies, ammonia is evolved.

3. Albumen is precipitated, by solution of muriate of mercury, in a curdy form; not immediately, however, if the solution be very dilute. Nitro-muriate of tin precipitates it, but less readily. Infusion of galls, containing in 100 parts 2½ of solid extract, has no immediate effect on a solution containing 1-1000th part of albumen, but, after some time, a precipitate ensues. Goulard's extract occasions an abundant dense precipitate. Nitrate of silver, and muriate of gold, throw down a sediment; and a concentrated solution of alum coagulates undiluted albumen.

4. On exposure to the atmosphere in a moist state, albumen passes at once to the state of putrefaction.

5. When nitric acid is poured on coagulated albumen in a retort, and a gentle heat is applied, azotic gas is disengaged, which proceeds, not from the acid, but from the animal matter.

6. Albumen, like gelatine, is precipitated by tan; but the precipitate is characterized by very different appearances and properties.

7. Albumen forms a large part of the blood, and of the solid parts of animals; and, with the exception of water, perhaps com-

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* For an account of the preparation of glue, see Nicholson's Journal, 8vo. ii. 235.

poses the largest part of the animal body.—It is used in clarifying solutions of sugar and other liquids.

SECTION III.

Animal Mucilage, or Mucus.

This solution has been supposed to be merely a modification of gelatine ; but, from the experiments of Dr. Bostock, it appears to be characterized by very different properties. These properties may be exhibited by saliva, diffused by agitation in water, or by agitating an oyster in water.

1. Mucilage does not coagulate on the application of heat ; nor does it gelatinate, when its heated solution cools.

2. It is not precipitated by an infusion of tan ; but, after some time, a slight turbidness is perceptible. This, however, appears to be owing to the presence of a small portion of gelatine.

3. Muriate of mercury, which is a delicate test of albumen, has no effect on mucilage.

4. Mucus is precipitated by Goulard's extract of lead, which appears to be the appropriate test of this animal fluid.

SECTION IV.

Gluten or Fibrin.

I. 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 water upon it, till a white fibrous matter alone remains.

For the purpose of submitting gluten to a series of experiments, Mr. Hatchett obtained it by digesting shreds of lean beef, during fifteen days, in water, which was changed daily, the temperature being such as not to excite putrefaction. The shreds of muscle were then boiled for five hours every day, during three weeks, changing the water every day ; and, finally, the residue was put into a press, and dried by the heat of a water bath.

II. Gluten has the following characters :

1. It has a white colour, and is destitute of taste and smell. It is soft and elastic, and becomes of a deeper colour on drying.

2. It undergoes no change, when exposed to the air in a moist state ; nor is it changed by being kept under water.

3. When exposed to heat it contracts, and moves like a slip of horn, exhaling at the same time a smell of burning feathers. Exposed to a stronger heat in close vessels, it yields water, carbonate of ammonia, a thick heavy fetid oil, and carbonic acid, and hydro-carburet gasses.—It leaves a larger proportion of charcoal, than either gelatine or albumen.

4. It is insoluble in water, except by the heat of a Papin's digester, and also in alcohol, ether, and oils.

5. It is readily soluble in acids. Sulphuric acid dissolves it and acquires a deep-brown colour; charcoal is precipitated, and acetic acid is formed. Muriatic acid converts it into a green jelly. Acetic, citric, oxalic, and tartarous acids, dissolve it; and the solutions, when concentrated, assume the appearance of jelly.

6. From acid solutions, alkalies precipitate gluten, in flakes, which are soluble in hot water, and which resemble gelatine in properties.

7. Diluted nitric acid separates a larger quantity of azotic gas from gluten, than from any other animal substance. The dissolved portion, when concentrated by evaporation, and dissolved in hot water, is precipitated by tan and nitro-muriate of tin, and possesses, therefore, the characters of gelatine.

8. Concentrated solutions of potash and soda dissolve gluten, evolve ammonia, and afford a compound resembling soap.

SECTION V.

Urea.

I. Urea may be obtained by the following process:—Evaporate, by a very gentle heat, a portion of human urine, voided six or eight hours after a meal, to the consistence of syrup. In this state it concretes, on cooling, into a crystalline mass. Pour on this, at different times, four parts of alcohol, and apply a gentle heat, which will effect the solution of the greater portion. Distil the solution by alcohol in a retort, till it acquires the consistence of syrup, which is to be poured out of the retort. On cooling, it forms a crystallized substance, which is the urea.

II. 1. Urea has the form of crystalline plates, crossing each other in various directions. It has a yellowish-white colour; a smell somewhat like that of garlic; is viscid, and difficult to cut; and has an acrid strong taste. It deliquiates, when exposed to the air, into a thick brown liquid. It is extremely soluble in water, and absorbs caloric during solution. Alcohol dissolves it readily, but in less proportion; and the alcoholic solution yields crystals more readily than the watery one.

2. The concentrated solution of urea, in water, yields, on the addition of nitric acid, a copious precipitate of bright pearl-coloured crystals. No other acid produces this singular effect.

3. The concentrated solution of urea, in water, is brown; but becomes yellow, when largely diluted. Infusion of galls gives it a yellowish-brown colour, but causes no precipitate; nor is it precipitated by infusion of tan.

4. When heat is applied to urea, it melts, swells, and evaporates, with an insufferably fetid smell. By distillation, it yields above 2-3ds its weight of carbonate of ammonia; about 1-4th of benzoic acid; besides charcoal, carburetted hydrogen, and muriates of soda and ammonia.

5. The solution of urea, in water, putrefies, and is slowly decomposed; but much more rapidly, if a little gelatine be added.

6. When a mixture of urea, with one-fourth its weight of diluted sulphuric acid, is distilled, a quantity of oil appears on the surface, which concretes by cooling; acetic acid passes over into the receiver; and sulphate of ammonia remains in the retort. The repetition of this process converts the whole of a portion of urea into ammonia and acetic acid.

7. Nitric acid acts rapidly on urea; nitrous, azotic, and carbonic acid gases, are disengaged; and prussic acid and ammonia are generated.

8. Muriatic acid dissolves urea without alteration.—Oxy-muriatic acid gas converts it into carbonate and muriate of ammonia.

9. The pure fixed alkalies dissolve urea, with a disengagement of ammonia.

10. Urea has the property of changing the form of the crystals of muriate of soda; a solution of that salt, mixed with one of urea, affording, on evaporation, octohedral crystals. Muriate of ammonia, on the contrary, which usually crystallizes in octohedrons, has the form of its crystals altered, by similar treatment, to that of cubes.

SECTION VI.

Animal Resins.

The properties of animal resins have not been fully investigated; but, so far as they have hitherto been examined, they appear to differ considerably from vegetable resins.

I. The resin of bile may be obtained by the following process:—To 32 parts of recent ox bile, add one of concentrated muriatic acid. When the mixture has stood some hours, strain it, in order to separate a white coagulated substance. Pour the filtered liquor, which has a fine green colour, into a glass vessel, and evaporate by a gentle heat. At a certain point of concentration, a green sediment falls down, which, after being separated from the liquid part, and washed, affords resin.

1. The resin of bile has a dark-brown colour; but, if spread out fine, on a white ground, it exhibits a bright grass-green. It is intensely bitter.

2. At about 122° it melts, and in a high temperature burns rapidly. It is soluble both in cold and hot water, and still more soluble in alcohol, from which it is in part precipitated by water.

3. With pure alkalies it combines, and forms a compound, which has been compared to soap. From these it is precipitated unchanged by acids.

4. When further oxygenized, by adding oxy-muriatic acid to bile, the resinous portion has its properties considerably changed; it acquires the colour and consistence of tallow; melts at 104°; and dissolves in alcohol and in hot water.

5. Besides this resin, there are several animal substances which possess similar qualities. Such are the ear-wax, ambergris, castor, &c.; for an account of which the reader may consult the 5th volume of Thomson's Chemistry.

SECTION VII.

Animal Sugar.

Sugar enters pretty largely into the composition of milk; and into the urine, when altered by disease. It may be obtained from milk by the following process:

I. Let whey be evaporated to the consistence of honey, and allowed to cool. It concretes into a solid mass, which is to be dissolved in water, clarified by white of eggs, filtered, and again evaporated to the consistence of syrup. On cooling, a number of brilliant white crystals are deposited, which are the sugar of milk.

1. Sugar of milk has a sweetish taste, and no smell.

2. It requires for solution, seven parts of water, and is insoluble in alcohol. In these properties it differs from common sugar, and also in its relation to nitric acid, which will be afterwards stated.

II. The urine of diabetic patients yields sugar on evaporation, which approaches more nearly in its characters to those of vegetable sugar, but cannot, like the latter, be made to crystallize.

SECTION VIII.

Animal Oils.

Animal oils differ from the vegetable oils, in being generally solid at the temperature of the atmosphere, but are similar to them in other properties. Among animal oils, may be ranked butter, tallow, lard, suet, spermaceti, &c.

Spermaceti bears some resemblance to wax, but differs from it in other properties. It is more readily fusible; is less soluble in boiling alcohol, of which it requires 150 times its weight; it is copiously dissolved by boiling ether; and the solution, on cooling, becomes a coagulated mass. Pure potash acts on it more remarkably than on wax; and the compound is quite soluble. A heated solution of ammonia affords a liquid, which is not precipitated by cooling, or by the addition of water; but is decomposed by acids.

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 resembling spermaceti, and called by the French chemists *adipocire.* 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 substance thus obtained, may be bleached, by exposure to the oxygenized muriatic acid gas.

Adipocire has a light-yellow colour, the consistence of tallow, and a homogeneous texture. It melts at an inferior temperature to either of the foregoing bodies. Cold alcohol has little action, but when heated, dissolves it rapidly. On cooling, it is deposited nearly white, and the alcohol has acquired a yellow tinge. Boiling ether dissolves nearly one-fourth, which separates, nearly white, on cooling. Fixed alkalies act on this, as on wax and spermaceti. Cold ammonia scarcely attacks it, and in this respect it differs from both the preceding substances.

SECTION IX.

Animal Acids.

Of the acids, that have hitherto been discovered to enter into the composition of animal substances, several have already been described, viz. the phosphoric, sulphuric, muriatic, carbonic, bonzoic, acetic, and malic. Besides these, the following are either component parts of animal substances, or are formed by treating them with chemical agents.

I. The *uric acid*, or *lithic acid*, exists in human urine, even in its most healthy state. The substance, occasionally voided along with the urine, and called gravel, consists for the most part of uric acid; and this acid forms, also, one of the most common ingredients of urinary calculi. One species of calculus, which resembles wood in appearance, is almost entirely composed of it. In this state it has a brown colour; is hard, and crystallized in small scales.

1. Uric acid, when pure, is destitute of colour, taste, and smell; it dissolves in 1720 parts of cold water, or in 1150 parts of boiling water; from which, on cooling, much of the acid precipitates. The solution reddens vegetable blue colours, and combines readily with pure alkalies. Fixed alkaline solutions dissolve a considerable quantity of uric acid, if the alkali be in excess. The saturated compounds, however, of uric acid with alkalies, termed urates, are not much more soluble than the acid itself. The combination of uric acid with soda, constitutes the principal part of the concretions found near the joints of gouty persons.

2. Nitric acid dissolves the uric acid, and the solution stains the skin of a pink colour. If the solution be boiled, azotic and carbonic acids escape, and prussic acid is formed; and on evaporation to dryness, a bright-red mass remains.

3. When the uric acid is distilled, about one-fourth its weight of a yellow sublimate arises, which contains no uric acid; but a new and peculiar one combined with ammonia. A few drops of thick oil make their appearance; and carbonate of ammonia, with some prussic acid, water, and carbonic acid, are obtained. In the retort there remains about 1-6th of charcoal.

II. The *rosacic acid* is well know to physicians, as a deposit from the urine at certain stages of fever, and other diseases, under the name of lateritious sediment.—According to Proust, this sediment contains, mixed with uric acid and phosphate of lime, a peculiar acid, which he terms the rosacic, from its resemblance in colour to that of the rose. This acid, he observes, differs chiefly from the uric, in being very soluble in hot water; in having little tendency to crystallize; and in precipitating muriate of gold of a violet colour.

III. The *amniotic acid* has been discovered by Fourcroy and Vauquelin, in the liquor of the amnios of the cow, from which, by slow evaporation, it separates in white crystals. It has a brilliant white appearance; a slight degree of sourness; reddens vegetable blues; is scarcely soluble in cold water, but readily in hot, from which it separates, on cooling, in long crystals. It is also soluble in heated alcohol. It combines readily with alkalies.

IV. The *lactic acid* forms a component part of sour milk; from which the acid may be obtained by gently evaporating it to about 1-8th; filtering to separate the curd; and adding lime-water to the residue. An earthy precipitate is formed; and the lime combines with the acid, from which it may be precipitated by oxalic acid. The lactic acid is thus obtained in an impure state, dissolved in water. Evaporate the solution to the consistence of honey; on this pour alcohol, and filter the solution. When the alcohol is separated by distillation, the lactic acid remains pure.

This acid has a yellow colour, is not susceptible of being crystallized, and attracts the humidity of the air. It combines with the alkalies and earths, and forms deliquescent salts. It dissolves iron and zinc, with a production of hydrogen gas. It unites also with the oxides of other metals. In its properties, it bears most resemblance to acetic acid.

V. The *saccholactic acid* is formed by pouring on powdered sugar of milk, in a stopped retort, four times its weight of nitric acid, and distilling off a considerable portion of the liquor. On leaving it to crystallize, oxalic acid is obtained; but if, instead of this, the liquid be suddenly diluted with water, a white sediment forms, which may be separated by decantation and washing.

It may also be obtained by pouring on one part of gum-arabic in a stoppered retort, two parts of nitric acid; applying heat a short time, till a little nitrous and carbonic acid gases have come over, and then allowing the mixture to cool. A white powder gradually separates, from which the liquid is to be decanted. The powder, after being washed several times with cold water, is saccholactic acid.

This acid is about 1-4th more soluble in hot than in cold water. Of the former it requires 80 parts. The solution is acid, and reddens the colour of litmus. It combines with alkalies, &c. and forms a genus of salts called Saccholactates.

VI. The *sebacic acid* may be obtained from various species of animal fat. The simplest process for separating it is that of

Guyton. To hogs'-lard, melted in an iron kettle, add pulverized quicklime, and stir the mixture for a few minutes, raising the heat towards the end of the process. When cold, the lard will be found to have less solidity. Pour on it a large quantity of water; boil them together, and filter the liquid. A brown acid salt will separate on cooling, consisting of lime, united with sebacic acid. This salt is contaminated with an admixture of oil, from which it may be separated by a degree of heat barely sufficient to decompose the oil. Re-dissolve and crystallize the residue; and, when again dry, distil it with 1-3d its weight of sulphuric acid, diluted with water. Its purity from the latter acid may be ascertained by its affording, with a solution of acetate of lead, a precipitate soluble in nitric acid.

1. The sebacic acid is liquid, white, and has a penetrating smell. It reddens vegetable colours.

2. By distillation it becomes yellow, gives carbonic acid, and is partly decomposed.

3. It unites with alkalies; and, when mingled with nitric acid, dissolves gold.

4. Nitrate and acetate of lead give a precipitate, soluble in acetic acid. It decomposes the muriate of mercury.

VII. The *prussic acid* is formed, chiefly during the decomposition of animal substances in high temperatures. Three parts of blood, evaporated to dryness in an iron dish, are to be mixed with one part of subcarbonate of potash (common pearlash), and calcined in a crucible, which should be only 2-3ds filled by the materials, and covered with a lid. The calcination must be continued, with a moderate heat, as long as a blue flame issues from the crucible; and when it becomes faint, and likely to be extinguished, the process must be stopped. Throw the mass, when cold, into 10 or 12 parts of water; allow it to soak a few hours; and then boil them together in an iron kettle. Filter the liquor, and continue pouring hot water on the mass, as long as it acquires any taste.—To this solution, add one, composed of two parts of alum and one of sulphate of iron, in 8 or 10 of boiling water; and continue the mixture as long as any effervescence and precipitation ensues. Wash the precipitate several times with boiling water. It will have a green colour; but, on the addition of a quantity of muriatic acid, equal in weight to twice that of the sulphate of iron which has been used, it will assume a beautiful blue colour. Wash it again with water, and dry it in a gentle heat. In this state it is the pigment called Prussian blue, which consists of a mixture of prussiate of iron, with alumine.—Its properties have already been described. (Chap. xviii. sect. 9. iv.)

From prussiate of iron, the prussic acid may be separated by the following process:

Mix two ounces of red oxide 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 distil 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 alkalies and earths.

Prussic acid has the following properties:

1. It has a sweetish taste, and a smell resembling that of bitter almonds.

2. It does not redden blue vegetable colours.

3. It precipitates sulphurets, and curdles soap.

4. It separates alumine from nitric acid. Oxygenized muriatic acid entirely decomposes it.

5. It does not appear to have a strong affinity for alkalies; nor does it take them from carbonic acid; for no effervescence arises on adding it to a solution of alkaline carbonates. On the contrary, its combinations with alkalies and earths are decomposed by exposure to carbonic acid, even when highly diluted, as in atmospheric air. It readily combines, however, with pure alkalies; destroys their alkaline properties, and forms crystallizable salts.

6. It does not precipitate iron blue, but green; and this green precipitate is soluble in acids. The rays of light render the green precipitate blue; as do also the addition of metallic iron, or sulphurous acid.

VIII. The *zoonic acid* has been shown by Thenard to be merely the acetous, holding some animal matter in solution. The *formic* acid, or acid of ants, was submitted to a course of experiments by Fourcroy and Vauquelin, who inferred that it is merely a mixture of acetic and malic acids. This conclusion has been set aside by the recent experiments of Suersen, which have proved that the formic is really a peculiar acid, approaching the acetic most nearly in its qualities. (Thomson's Chemistry, ii. 313.)

A full account of all the varieties of the more complicated animal substances, which result from the combination, in various proportions, of those which have already been enumerated, would lead me into a minuteness of detail, entirely inconsistent with the plan of this work. A very full and perspicuous history of them may be found in the 5th volume of Dr. Thomson's Chemistry, from which excellent work I have chiefly derived the materials of the following table. It is intended to comprehend a general abstract of the composition of animal substances, so far as they have hitherto been made the subjects of investigation; and may, perhaps, be sufficient for the purposes of the general student.

TABLE

SHEWING

THE COMPOSITION OF VARIOUS ANIMAL SUBSTANCES.

Bile. In 100 parts, water 70; resin 4; saccharine matter 4; albumen 0.005 soda 0.005; together with a minute quantity of muriate and sulphate of soda; phosphates of soda and lime; and oxide of iron.

Blood. 1st *Serum.* Albumen; mucus*; carbonate and muriate of soda; phosphates of soda and lime; hydrosulphuret of ammonia; pure soda; and benzoic acid. 2. *Crassamentum.* Fibrin, albumen, soda, sub-phosphate of iron.

Bones. In 100 parts, phosphate of lime from 50 to 90; carbonate of lime from 1 to 2; (in the bones of inferior animals a little phosphate of magnesia) gelatine from 12 to 30; very little sulphate of lime; oil and cartilage in uncertain proportions.

Brain. Peculiar animal matter most like albumen; phosphates of lime, soda, and ammonia; very minute quantity of sulphate of lime.

Calculi *Biliary.* 1st species white and crystalline, shape oval, composed of adipocire; 2d species polygonal, chiefly adipocire, with very little albumen; 3d (found mostly in oxen) inspissated bile.

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* On the authority of Dr. Bostock, who finds no gelatine in serum.

Calculi *Gouty.* Urate of soda.

—— *Intestinal,* seven species, 1st. super-phospate of lime; 2d. phosphate of magnesia; 3d. ammoniaco-magnesian phosphate; 4th. biliary; 5th. resinous; 6th. fungous; 7th. hairy.

—— *Urinary.* Four principal species; 1st. various shades of yellow, uric acid; or chocolate brown, urate of ammonia: 2d. dull yellowish white, phosphate of lime; 3d. clear white, ammoniaco-magnesian phosphate; 4th. mulberry-shaped, oxalate of lime; besides various combinations of these with each other.

Cartilage. Coagulated albumen.

Cerumen. (Ear-wax.) Inspissated oil; colouring matter; soda; phosphate of lime.

Crusts. (Of crabs, lobsters, &c.) In 100 parts, 60 carbonate of lime, 14 phosphate of lime, 26 cartilage.

Eggs. 1. *White.* In 100 parts, water 80; albumen 16; mucus 4.

2. *Yolk.* Water, oil, albumen, gelatine, and sulphur.

3. *Shells.* In 100 parts, 90 carbonate, 6 phosphate of lime, 4 animal matter.

Enamel of Teeth. In 100 parts, 78 phosphate of lime, 6 carbonate of lime, gelatine and loss 16.

Epidermis. See Skin.

Excrement. See Feces.

Feces. In 100, water 73, vegetable and animal matter 7, bile 9; albumen; extractive; besides carbonate, muriate, and sulphate of soda, and earthy phosphates.

Hair. Gelatine; coagulated albumen; sulphur; oil; oxides of iron and manganese; phosphate, sulphate, and carbonate of lime; muriate of soda; and silex.

Horn. Chiefly coagulated albumen; little gelatine; not 1-500 earthy phosphate.

—— Buck's and hart's, same as bone, but with more cartilage.

Humour *aqueous.* Chiefly water, with very little albumen, gelatine, and muriate of soda.

—— *vitreous.* Same, with more animal matter.

—— *Crystalline.* Same, with little water.

Ligaments. Gelatine, coagulated albumen.

Liquor *of the amnios.* In 100 parts, 98 water, the rest albumen, muriate of soda, soda, phosphate of lime, lime.

LIQUOR *of the pericardium.* In 100 parts, 92 water, albumen $5\frac{1}{2}$, mucus 2, muriate of soda $\frac{1}{2}$.

MEMBRANE. A modification of gelatine.

MILK. 1. Oil or cream ; 2. curd or albumen ; 3. whey, containing sugar of milk, muriates of potash and soda, phosphate of lime, acetic acid, phosphates of magnesia and iron.

MUSCLE. Chiefly fibrin, with albumen, gelatine, and extractive, phosphates of soda, ammonia, and lime, carbonate of lime, and a little sulphuric acid and potash.

NAILS. Resemble horn. Chiefly coagulated albumen.

SALIVA. Mucus ; albumen ; muriate of soda ; phosphates of soda, ammonia, and lime.

SCALES. *Of serpents and amphibia*, resemble horn.

———— *Of fish*, alternate layers of membrane and phosphate lime.

SEMEN. In 100 parts, 90 water, 6 mucus, 3 phosphate of lime, 1 soda.

SHELLS *porcellaneous.* Carbonate of lime and gelatine.

————*pearly* (oyster, &c.) alternate layers of carbonate of lime, and coagulated albumen.

SILK. Modified gelatine, resin.

SKIN. *Cuticle or epidermis*, coagulated albumen.

————*Cutis or true skin*, a modification of gelatine.

SYNOVIA. In 100 parts, water 80, fibrous matter 12, albumen 4, muriate of soda 1.7, soda 0.07, phosphate of lime 0.07.

TEARS. Water, mucus, muriate of soda, phosphates of lime and soda, soda.

TEETH. In 100 parts, 58 to 64 phosphate of lime, 4 to 6 carbonate, 20 to 30 cartilage.

URINE. Water, phosphoric acid, phosphate of lime, phosphate of magnesia, carbonic acid, carbonate of lime, uric acid, rosacic acid, benzoic acid, gelatine, albumen, urea, resin, muriate of soda, phosphates of soda and ammonia, muriate of ammonia, sulphur.

ZOOPHYTES. Equal parts of carbonate of lime, and animal matter.

PART II.

DIRECTIONS FOR EXAMINING MINERAL WATERS, AND MINERAL BODIES IN GENERAL.

CHAPTER I.

ANALYSIS OF MINERAL WATERS.

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.

Before proceeding, however, to the analysis of a water, it is proper to inquire into its natural history, and to examine attentively its physical characters. The nature of the strata in the neighbourhood of the spring, will often furnish useful suggestions respecting the contents of the water; the period of the year should be stated at which the analysis was performed; and whether after a rainy or dry season. The temperature of the water must be carefully observed, as it issues from the spring; and the quantity inquired into, which it yields in a given time. The sensible qualities of taste, smell, degree of transparency, &c. are also best ascertained at the fountain-head. The specific gravity of the water may be found by weighing a bottle, which is capable of containing a known weight of distilled water, at a certain temperature, filled with the water, under examination, at the same temperature. It is proper, also, to examine, on the spot, the channel through which the water has flowed ; to collect any deposit that may have been formed ; and to investigate its nature.

The effects of heat on the water may be next tried.—Many waters lose their transparency when their temperature is raised, and let fall a considerable deposit. The quality of this may, in some degree, be conjectured from its appearance. If its colour be brownish-yellow, it consists, either wholly or chiefly, of oxide of iron ; if white, or nearly white, it is composed principally of the earthy carbonates. A mineral water, containing iron, deposits that metal also, when exposed to the atmosphere ; and a thin pellicle forms on its surface, whether stagnant in a natural reservoir, or collected in a separate vessel. By this exposure, iron may be sometimes discovered in a water, though not easily detected at first ; because it becomes further oxydized, and more sensible to the action of tests. Sulphuretted hydrogenous waters deposit a sediment, even when preserved in a well-closed vial ; the hydrogen quitting the sulphur, which settles in the form of a white powder.

SECTION I.

Examination of Mineral Waters by Re-agents.

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 re-agents ; *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.

In many instances, however, a mineral water may contain a saline, or other ingredient, but in such small quantity as to escape discovery by tests. It is therefore adviseable to apply the tests of fixed substances to the water, after reducing its bulk one-half, or more, by evaporation, as well as in its natural state.

The use of tests, or re-agents, has been employed by Mr. Kirwan to ascertain by a careful examination of the precipitate, not only the *kind*, but the *quantity*, of the ingredients of mineral waters. This will be best understood from an example. It is an established fact, that 100 parts of crystallized muriate of soda, when completely decomposed by nitrate of silver, yield, as nearly as possible, 235 of precipitate. From the weight of the precipitate, separated by nitrate of silver from a given quantity of any water, it is therefore easy, when no other muriatic salt is present, to infer, what quantity of muriate of soda was contained in the water; since every hundred grains of muriated silver indicate, pretty accurately, 42½ of crystallized common salt. The same mode of estimation may be applied in various other instances; and the rule for each individual case is given by Mr. Kirwan, in part ii. chap. 2. of his "Essay on the Analysis of Mineral Waters." In most instances, also, it will be found stated in the following description of the use of the various re-agents.

I. *Infusion of Litmus, Syrup of Violets, &c.*

The infusion of litmus is prepared by steeping this substance, first bruised in a mortar, and tied up in a linen 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 the scrapings 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 well 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 by sulphuretted hydrogen, when experiment shows that the reddening cause is volatile, add a little lime-water, or, in preference, barytic 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, along with carbonic acid, in the same water; which will be determined 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.) The dark-blue paper, which is generally wrapped round loaves of refined sugar, is not discoloured by carbonic acid or sulphuretted hydrogen, but only by the stronger acids.

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 alkalies and pure earths, and by carbonated alkalies and earths.

2. Turmeric paper and tincture are changed to a reddish-brown by alkalies, 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 alkalies 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 will be much less remarkable, when the water has been boiled.

4. Syrup of violets, when pure, is, by the same causes, turned green*; as is also paper stained with the juice of the violet, or with the scrapings of 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 oxide, or, if oxydized 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 by 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, the iron, as often happens, is dissolved both by carbonic acid and by a fixed acid. A neat mode 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, by a slowly-formed and dark cloud, surrounding the re-agent. (Kalproth, vol. i. p. 279.)

IV. *Sulphuric Acid.*

1. Sulphuric acid discovers, by a slight effervescence, the presence of carbonic acid, whether uncombined or united with alkalies or earths.

2. If lime be present, whether pure or uncombined, the addition of sulphuric acid occasions, after a few days, a white precipitate.

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* 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.

If from a mineral water, which has been well boiled, the addition of sulphuric acid extricates sulphuretted hydrogen gas, Mr. Westrumb infers the presence of hydro-sulphuret of lime. In this case, sulphate of lime is precipitated. (Nich. xviii. 40.)

3. Barytes is precipitated instantly, in the form of a white powder.

4. Nitric and muriatic salts, in a dry state, or dissolved in very little water, 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 fuming red nitrous acid has been recommended as a test distinguishing between hepatic waters that contain hydro-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 fetid smell arises; in the latter, a slight cloudiness only appears, and the smell of the water becomes less disagreeable. If a water, after boiling, gives a precipitate of sulphur, on adding nitrous acid, Westrumb concludes that this is owing to hydro-sulphuret of lime.

VI. *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, p. 88.)

The oxalate of ammonia, or of potash (which may easily be formed by saturating the respective carbonates of these alkalies with a solution of oxalic acid), are not liable to the above objection, and are preferable, as re-agents, 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. A precipitation will then be produced.

The quantity of lime, contained in the precipitate, may be known, by first calcining it with access of air, which converts the oxalate into a carbonate; and by expelling, from this last, its carbonic acid, by calcination, with a strong heat, in a covered crucible. According to Dr. Marcet, 117 grains of sulphate of lime give 100 of oxalate of lime, dried at 160° Fahrenheit.

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.

VII. *Pure Alkalies and carbonated Alkalies.*

1. The pure fixed alkalies 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 grains to 500, without being discovered by pure fixed alkalies. As the alkalies precipitate so many substances, it is evident that they cannot afford any very precise information, when employed as re-agents. 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; and its precise composition must be ascertained by rules which will presently be given.

2. Pure fixed alkalies also decompose all salts with basis of ammonia, which becomes evident by its smell (except the salts are dissolved in much water), and also by the white fumes it exhibits when a stopper, moistened with muriatic acid, is brought near.

3. Carbonates of potash and of 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 or nickel 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; raise it nearly to 212° Fahrenheit; and then add pure ammonia. If any precipitation now occurs, we may infer the presence of magnesia. It must be acknowledged, that zircon, yttria, and glucine, would escape discovery by this process; but they have never yet been found in mineral waters; and their presence can scarcely be expected.

VIII. *Lime-Water.*

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 arsenous acid (common arsenic) be contained in a liquid, lime-water, when added, will occasion a precipitate, consisting of lime and arsenous acid, 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.

IX. *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, the barytic solution may at any time be immediately prepared. In discovering carbonic acid, 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. The quantity of the precipitated substance, indicated by the weight of the precipitate, will be stated in No. XV.

X. *Metals.*

1. Of the metals, silver and mercury are tests of the presence of hydro-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 the bottle, a blackish powder separates from it. Silver is speedily tarnished by the same cause.

2. The metals may be used also as tests of each other, on the principal 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.

XI. *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 oxygen 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, in a vial completely filled by the mixture. If an oxide of iron be precipitated in the course of a few days, the water may be inferred to contain oxygen gas.

XII. *Sulphate, Nitrate, and Acetate 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 its solvent, combines with the muriatic acid, and forms a flaky precipitate, which, at first, is white, but, on exposure to the sun's light, acquires a blueish, and finally a black 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. The same quantity of muriate of silver (1000 parts) indicates, according to Kirwan, 454¾ of muriate of potash. 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 alkalies and earths. The agency of the alkalies and earths may be prevented, by previously saturating them with a few drops of the same acid in which the silver is dissolved.

3. The nitrate and acetate of silver are decomposed by the sulphuric and sulphurous 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 remove uncertainty, whether a precipitation be owing to sulphuric or muriatic acid, a solution of sulphate of silver may be employed, which, when no uncombined alkali or earth is present, is affected only by the latter acid. According to Professor Pfaff, one part of muriatic acid of the specific gravity, 1.15, diluted with 70,000 parts of water, barely exhibits a slight opaline tinge, when tested with nitrate of silver; and, when diluted with 80,000 parts of water, it is not affected at all. (Nicholson, xvii. 361.)

4. The solutions of silver are also precipitated by sulphuretted hydrogen, and by hydro-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 great part, in dilute nitrous acid, which is not the case if occasioned by muriatic or sulphuric acid.

5. The solutions of silver are precipitated by extractive matter; but, in this case, also, the precipitate has a dark colour, and is soluble in nitrous acid.

XIII. *Nitrate and Acetate of Lead.*

1. Acetate 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 acetate is also a test of sulphuretted hydrogen and of hydro-sulphurets of alkalies, which occasion a black precipitate; and, if a paper, on which characters are traced with a solution of acetate of lead, be held over a portion of water containing sulphuretted hydrogen gas, they are soon rendered visible; especially when the water is a little warmed.

3. The acetate 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 alkalies and earths (if any be suspected) must be saturated with acetic or acetous acid. (*b.*) The sulphates must be decomposed by acetate or nitrate of barytes, and the

muriates by acetate or nitrate of silver. The filtered liquor, if boracic acid be contained in it, will continue to give a precipitate, which is soluble in nitric acid of the specific gravity 1.3.

4. Acetate of lead is said, also, by Pfaff to be a very delicate test of carbonic acid; and that it renders milky water, which contains the smallest possible quantity of this acid.

XIV. *Nitrate of Mercury, prepared with and without Heat.*

This solution, differently prepared, is sometimes employed as a test.

1. The solution of nitrate of mercury, prepared without heat*, has been found by Pfaff to be a much more sensible test of muriatic acid than nitrate of silver. Its sensibility, indeed, is so great that 1 part of muriatic acid, of the spec. grav. 1.50 diluted with 300,000 parts of water, is indicated by a slightly dull tint ensuing on the addition of the test.

2. It is, at the same time, the most sensible test of ammonia, one part of which, with 30,000 parts of water, is indicated by a slight blackish yellow tint, on adding the nitrate of mercury.

3. The nitrate of mercury is also precipitated by highly diluted phosphoric acid; but the precipitate is soluble in an excess of phosphoric or nitric acid, which is not the case if it has been occasioned by muriatic acid.

XV. *Muriate, Nitrate, and Acetate 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 alkali; but the precipitate occasioned by carbonates is soluble in dilute muriate or nitric acid, with effervescence, and may even be prevented by adding, previously, a few drops of the same acid as that contained in the barytic salt, which is employed.

One hundred grains of dry sulphate of barytes contain (according to Klaproth, vol. i. 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 sp. gr. 2240; according to Thenard, after calcination, about 25; and, according to Mr. Kirwan, after ignition, 23.5 of real acid. The same chemist states, that 170 grains of ignited sulphate of barytes denote 100 of dried

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* See chap. xviii. sect. 5. vi.

sulphate of soda; while 136.36 of the same substance indicate 100 of dry sulphate of potash; and 100 parts result from the precipitation of 52.11 of sulphate of magnesia.

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 grains of sulphate of lime.

2. Phosphoric salts occasion a precipitate also, which is soluble in muriatic acid without effervescence.

XVI. *Prussiates of Potash and of Lime.*

Of these two, the prussiate of potash is the most eligible. When pure, it does not speedily resume a blue colour on the addition of an acid, nor does it *immediately* precipitate muriate 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 alkalies 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.

In using the prussian test for the discovery of iron, considerable caution is necessary, in order to attain accurate results. The prussiate should, on all occasions, be previously crystallized; and the quantity of oxide of iron, essential to its constitution, or at least an invariable accompaniment, should be previously ascertained in the following manner. Expose a known weight of the crystallized salt to a low red-heat in a silver crucible. After fusing and boiling up, it will become dry, and will then blacken. Let it cool; wash off the soluble part; collect the rest on a filter; dry it, and again calcine it with a little wax. Let it be again weighed, and the result will show the proportion of oxide of iron present in the salt which has been examined. This varies from

22 to 30 and upwards per cent. When the test is employed for discovering iron, let a known weight of the salt be dissolved in a given quantity of water; add the solution gradually; and observe how much is expended in effecting the precipitation. Before collecting the precipitate, warm the liquid, which generally throws down a further portion of prussian blue. Let the whole be washed and dried, and then calcined with wax. From the weight of the oxide obtained, deduct that quantity which, by the former experiment, is known to be present in the prussiate that has been added; and the remainder will denote the quantity of oxide of iron, present in the liquid which is under examination.

3. Besides iron, the prussiated alkalies also precipitate muriate of alumine. No conclusion, therefore, can be deduced, respecting the non-existence of muriate of alumine from any process, in which the prussic test has previously been used. It will, therefore, be proper, if a salt of alumine be indicated by other tests, to examine the precipitate effected by prussiate of potash. This may be done by repeatedly boiling it to dryness with muriatic acid, which takes up the alumine, and leaves the prussiate of iron. From the muriatic solution, the alumine may be precipitated by a solution of carbonate of potash.

4. According to Klaproth (ii. 55.), solutions of yttria, (which earth, however, is not likely to be present in any mineral water) afford with the prussian test, a white precipitate, passing to pearl-grey, which consists of prussiate of yttria. This precipitate disappears on adding an acid, and hence may be separated from prussiated iron. The same accurate chemist states, that the prussian test has no action on salts with base of glucine (ib.); but that it precipitates zircon from its solutions. (ii. 214.)

The prussiated alkalies decompose, also, all metallic solutions, excepting those of gold, platina, iridium, rhodium, osmium, and antimony.

XVII. *Succinate of Soda and of Ammonia.*

1. The succinate of soda was first recommended by Gehlen, and afterwards employed by Klaproth (Contributions, ii. 48.) for the discovery and separation of iron. The salt with base of ammonia has also been used for a similar purpose by Dr. Marcet, physician to Guy's Hospital, in a skilful analysis of the Brighton chalybeate, which is published in the new edition of Dr. Saunders's Treatise on Mineral Waters.

The succinic test is prepared by saturating carbonate of soda or ammonia with this acid, already described, ch. xix. sect. 8.

In applying the test, it is necessary not to use more than is sufficient for the purpose; because an excess of it re-dissolves the precipitate. The best mode of proceeding, is to heat the solution containing iron, and to add gradually the solution of succinate, until it ceases to produce any effect. A brownish precipitate is obtained, consisting of succinate of iron. This, when calcined with a little wax, in a low red-heat, gives an oxide of iron, containing about 70 per cent. of the metal. From Dr. Marcet's experiments, it appears, that 100 grains of iron, dissolved in sulphuric acid, then precipitated by the succinate test, and afterwards burned with wax, give 148 of oxide of iron; that is, 100 grains of the oxide indicate about 67½ of metallic iron.

2. The succinates, however, it is stated by Dr. Marcet and Mr. Ekeberg, precipitate alumine, provided there be no considerable excess of acid in the aluminous salt. On magnesia it has no action, and hence may be successfully employed in the separation of these two earths. If 100 parts of octohedral crystals of alum be entirely decomposed by succinate of ammonia, they give precisely 12 parts of alumine calcined in a dull red-heat. The succinate of ammonia, it is stated by Mr. Ekeberg (*Journ. des Mines*, No. 70.), precipitates glucine; and the same test, according to Klaproth (ii. 214.), throws down zircon from its solutions.

XVIII. *Phosphate of Soda.*

An easy and valuable method of precipitating magnesia has been suggested by Dr. Wollaston. It is founded on the property which fully neutralized carbonate of ammonia possesses; first to dissolve the carbonate of magnesia, formed when it is added to the solution of a magnesian salt, and afterwards to yield the earth to phosphoric acid, with which and ammonia it forms a triple salt. For this purpose, a solution of carbonate of ammonia, prepared with a portion of that salt which has been exposed, spread on a paper, for a few hours to the air, is to be added to the solution of the magnesian salt sufficiently concentrated; or to a water suspected to contain magnesia, after being very much reduced by evaporation. No precipitate will appear, till a solution of phosphate of soda is added, when an abundant one will fall down. Let this be dried in a temperature not exceeding 100° Fahrenheit. One hundred grains of it will indicate 19 of pure magnesia, or about 64 of muriate of magnesia.

XIX. *Muriate of Lime.*

Muriate of lime is principally of use in discovering the presence of alkaline carbonates, which, though they very rarely occur, have sometimes been found in mineral waters. Carbonate of potash exists in the waters of Aix-la-Chapelle; that of soda, in the water of a few springs and lakes; and the ammoniacal carbonate was detected by Mr. Cavendish in the waters of Rathbone-place. Of all the three carbonates, muriate of lime is a sufficient indicator; for those salts separate from it a carbonate of lime, soluble with effervescence in muriatic acid.

With respect to the discrimination of the different alkalies, potash may be detected by the nitro-muriate of platina, which distinctly and immediately precipitates that alkali and its compounds, and is not affected by soda. Carbonate of ammonia may be discovered by its smell; and by its precipitating a neutral salt of alumine, while it has no action apparently on magnesian salts.

To estimate the proportion of an alkaline carbonate present in any water, saturate with sulphuric acid, and note the weight of real acid which is required. Now 100 grains of real sulphuric acid saturate 121.48 potash, and 78.32 soda.

XX. *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 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 alkali quitting the oil, whenever there is present in a water any substance, for which the alkali 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.

XXI. *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.)

XXII. *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.

TABLE,

Showing the 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. Acetate 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. Nitrate of mercury, XIV.

Acid, nitric. Sulphuric acid, IV. 4.

Acid, phosphoric. Solutions of barytes, XV. 2. Nitrate of mercury, XIV. 3.

Acid, sulphurous. 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 oxide of manganese.

Acid, sulphuric. Solution of pure barytes, IX. Barytic salts, XV. Acetite of lead, XII.

Alkalies in general. Vegetable colours, II. Muriate of lime, XIX.

Alumine dissolved by acids. Succinates, XVII.

Ammonia, by its smell, and tests, II. Nitrate of mercury, XIV. 2.

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 alkalies, VII.

Hydro-sulphuret of lime. Sulphuric acid, IV. Nitrous acid, V.

Iron dissolved by carbonic acid. Tincture of galls, III. 1. Prussiate of potash, XVI. 1. Succinate of ammonia, XVII.

Iron dissolved by sulphuric acid. Same tests, III. 3. XVI. 2. XVII.

Lime in a pure state. Water saturated with carbonic acid. Blowing air from the lungs. Oxalic acid, VI.

Lime dissolved by carbonic acid. Precipitation on boiling.—Caustic alkalies, VII. Oxalic acid, VI.

Lime dissolved by sulphuric acid. Oxalate of ammonia, VI. Barytic solutions, IX. and XV.

Magnesia dissolved by carbonic acid. Precipitation on boiling,—the precipitate soluble in dilute sulphuric acid.

Magnesia dissolved by other acids. Precipitated by pure ammonia, not by the carbonate, VII. 5. Phosphate of soda, XVII.

Muriates of alkalies. Solutions of silver, XII.

——— *of lime.* Solutions of silver, XII. Oxalic acid, and oxalate of ammonia, 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 alkalies by boiling. Succinates, XVII. 2.

Sulphate of lime. Barytic solutions, IX. and XV.—Oxalic acid, and oxalates, VI.—A precipitate by alkalies not soluble in dilute sulphuric acid.

Sulphurets of alkalies. Polished metals, X. Smell on adding sulphuric or muriatic acid.—Nitrous acid, V.

Sulphuretted hydrogen gas. By its smell. Infusion of litmus, I. Polished metals, X. Acetite of lead, XIII. 2.*

SECTION II.

Analysis of Waters by Evaporation.

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 2., 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 analysing 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 50 cubical inches, and

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* The vapour of putrefying animal or vegetable matter dissolved in water, according to Klaproth, vol. i. p. 590, often gives a deceptive indication of sulphuretted hydrogen.

furnished with a ground stopper and bent tube. The bottle is to be placed, up to its neck, in a tin kettle filled with brine, which must be kept boiling for an hour or two, renewing, by fresh portions of hot water, what is lost by evaporation. The disengaged gas is conveyed, by the bent tube, into a graduated jar, filled with, and inverted in, mercury, where its bulk is to be determined. On the first impression of the heat, however, the water will be expanded, and portions will continue to escape into the graduated jar, till the water has obtained its maximum of temperature. This must be suffered to escape, and its quanity be deducted from that of the water submitted to experiment.

In determining, with precision, the quantity of gas, it is necessary to attend to the state of the barometer and thermometer, and to other circumstances already enumerated, page 53. Rules for reducing observations made under different states of the barometer and thermometer, to a mean standard, will be given in the appendix. If a considerable proportion of gas be contained in a mineral water, the most commodious method of receiving it is into a small gazometer.

The gases, most commonly found in mineral waters, are *carbonic acid; sulphuretted hydrogen; azotic gas; oxygen gas;* and, in the neighbourhood of volcanoes only, *sulphurous acid gas.*

To determine the proportion of the gases, constituting any mixture obtained from a mineral water in the foregoing manner, the following experiments may be made. If the use of re-agents has not detected the presence of sulphuretted hydrogen, and there is reason to believe, from the same evidence, that carbonic acid forms a part of the mixture, let a graduated tube be nearly filled with it over quicksilver. Pass up a small portion of solution of potash, and agitate this in contact with the gas. The amount of the diminution will show how much carbonic acid has been absorbed; and, if the quantity submitted to experiment, was an aliquot part of the whole gas obtained, it is easy to infer the total quantity present in the water. The unabsorbable residuum consists, most probably, of oxygen and azotic gases; and the proportion of these two is best learned by the use of Dr. Hope's eudiometer, (see page 65.)

If sulphuretted hydrogen be present, along with carbonic acid, the separation of these two is a problem of some difficulty. Mr. Kirwan recommends that a graduated glass-vessel, completely filled with the mixture, be removed into a vessel containing nitrous acid. This instantly condenses the sulphuretted hydrogen, but not the carbonic acid gas. I apprehend, however, that a more eligible mode will be found to be, the condensation of the sulphuretted hydrogen by oxy-muriatic acid gas (obtained from muriatic acid and hyper-oxymuriate of potash); adding the latter gas very cautiously, as long as it produces any condensation. Or, perhaps, a better plan of effecting the separation (which, however, I have not at present an opportunity of trying) will be the following: Half fill a graduated vial with the mixed carbonic acid and sulphuretted hydrogen gases, and expel the rest of the water by oxy-muriatic acid gas. Let the mouth of the bottle be then closed with a well-ground stopper, and let the mixture be kept twenty-four hours. Then withdraw the stopper under water, a quantity of which fluid will immediately rush in. Allow the bottle to stand half an hour without agitation. The redundant oxy-muriatic acid gas will thus be absorbed; and very little of the carbonic acid will disappear. Supposing that, to 10 cubic inches of the mixed gases, 10 inches of oxy-muriatic gas have been added, and that, after absorption by standing over water, 5 inches remain: the result of this experiment shows, that the mixture consisted of equal parts of sulphuretted hydrogen and carbonic acid gases.

Mr. Westrumb ascertains the proportion of sulphuretted hydrogen and carbonic acid gases, by the following method. He introduces a known quantity of the water under examination into a glass vessel, from which proceeds a curved tube, terminating in a long cylinder, filled with lime-water. The gas is expelled by heat, and the precipitate collected. Every 20 grains indicate 10 cubic inches of carbonic acid. To determine the quantity of sulphuretted hydrogen, the same experiment is repeated, substituting a solution of super-acetate of lead. Hydro-sulphuret of lead is formed, in the proportion of 19 grains to 10 cubic inches of gas. This method, for several reasons which it would take too much room to state, is perhaps inferior to the one which I have just proposed.

Whenever this complicated admixture of gases occurs, as in the case of the Harrowgate-water, it is adviseable to operate separately on two portions of gas, with the view to determine, by the one, the quantity of carbonic acid and sulphuretted hydrogen; and that of azote and oxygen by the other. In the latter instance, remove both the absorbable gases by caustic potash; and examine the remainder in the manner already directed.

Azotic gas sometimes occurs in mineral waters, almost in an unmixed state. When this happens, the gas will be known by the characters already described as belonging to it, page 62. Sulphurous acid gas may be detected by its peculiar smell of burning brimstone, and by its discharging the colour of an infusion of roses, which has been reddened by the smallest quantity of any mineral acid adequate to the effect.

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 unglazed biscuit ware, made by Messrs. Wedgewood; but, as their surface is not perfectly smooth, and the dry mass may adhere so strongly as not to be easily 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 oxydized, as will appear from its reddish-brown colour.

1. In order to discover the quality and quantity of the ingredients, evaporate to dryness; weigh the residuum; 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 of the salts, 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. Lime and magnesia may also be separated by the use of the phosphate of soda, applied in the manner already described in the preceding section, No. XVIII.

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 alcoholic 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 extremely difficult to obtain them sufficiently distinct to ascertain their kind.

2. The nature of the saline contents must, therefore, be examined by tests, or re-agents.

The presence of an uncombined alkali will be discovered by the stained papers (p. 282.), and of acids by the tests (p. 280.). The vegetable alkali, 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 super saturation, with the tartarous acid, which gives a soluble salt with soda, but not with potash. Muriate of platina, also, is an excellent test of potash and its combinations; for, with the smallest portion of this alkali, or any of its salts, it forms a distinct and immediate precipitate;

while it is not at all affected by the mineral alkali or its compounds.

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 oxydized iron. Evaporate the solution to dryness. If it contain acetate 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 alkali. [See additions at the end.]

CHAPTER II.

EXAMINATION OF MINERALS.

SECTION I.

General Directions.

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. Those who are solicitous to become adepts in the art of mineral analysis, may read attentively the numerous papers of Vauquelin, Hatchett, and other skilful analysts, dispersed through various chemical collections; and also an admirable work of M. Klaproth, lately translated into English, entitled, "Analytical Essays towards improving the Chemical Knowledge of minerals," 2 vols. 8vo., published by Cadell and Davies, 1801.

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; 2d, SALTS; 3d, INFLAMMABLE FOSSILS; and, 4th, METALS, and their Ores.

I. 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 difficulty, 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 solvent 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.

II. SALTS.—Under this head Mr. Kirwan arranges "all those substances that require less than 100 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.

III. "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."

IV. 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 semi-metals, 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 oxydized, and the oxide 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.

SECTION II.

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 a filtering paper, 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 adviseable 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 saline matter, 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 distilled 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 directions sufficiently minute to enable any one to perform a complete analysis.

SECTION III.

Examination of Salts.

1. A solution of saline matter, obtained in the foregoing manner (see page 302.), 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 294.

(*b.*) *Alkalies.* These are characterized by their effect on vegetable colours, and by the other properties enumerated, page 82.

(*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 alkali precipitates a farther portion, we may infer that both earthy and metallic salts are contained in the solution. In the first case, add the alkaline 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 alkaline 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 alkaline 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 alkali, 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 alkali will remain unvolatilized. 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 the peculiar smell of that alkali. The vegetable and mineral alkalies may be distinguished by adding to the solution a little tartarous acid, which precipitates the former but not the latter; or by muriate of platina, which acts only on the vegetable alkali.

Having ascertained the basis of the salt, the acid will easily be discriminated. Muriated barytes will indicate sulphuric acid;

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* This application of heat will drive off, also, any excess of the ammoniacal carbonate, which might have retained in solution either yttria, glucine, or zircon. The alkaline salts may be separated from these earths, by boiling the mixture in water, filtering, and evaporating.

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.

SECTION IV.

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, barytes, zircon, glucine, and yttria), one or more may be expected in the composition of a mineral, 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, zircon, glucine, and yttria, 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 minerals, 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 be reduced 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, in a gentle heat, for two or three hours. Ascertain the loss of weight, in the manner pointed out, page 290, 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, after being well washed, 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 a red-heat, continued, with the access of air, till the

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* The sulphuric acid is chiefly eligible for stones of the magnesian genus.

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 85), 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 oxides. To separate the oxides, add prussiate of potash, till its effect ceases, and filter the solution, reserving the precipitate for future experiments.

(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 carbonate 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

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* Klaproth separates barytes from strontites by evaporating the solution of both in acid. The barytic salt, being less soluble, separates first ; and the strontitic is contained in the last portions.

† The bottom of a broken Florence flask answers this purpose extremely well, and bears, without breaking, the heat necessary to expel the sulphuric acid.

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. According to Klaproth (vol. i. 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 non-appearance 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, vol. i. p. 418. The magnesia, remaining in solution, may be precipitated by carbonate of potash; heat being applied, to expel the excess of carbonic acid.

Magnesia and alumine may, also, be separated by succinate of soda, which precipitates the latter earth only. (See Sect. 1. xvii. of the Chapter on Mineral Waters.)

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 one hour, in a low read-heat, and dissolving again in dilute nitric acid, which does not take up iron when thus oxydized.

(H.) The insoluble residue (A.) may contain alumine, silex, and oxides, of metals, so highly charged with oxygen as to resist the action of nitric and muriatic acids.

(*a.*) Add concentrated sulphuric acid, with a small quantity of potash, and evaporate the mixture to dryness, in the vessel described in the note, p. 308. 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 sulphate of alumine and potash, which will be easily soluble in warm water; and, from the solution, crystals of alum will shoot 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, i. 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*).

Alumine may be separated from oxide of iron by a solution of pure potash.

From whatever acid alumine is precipitated by fixed alkali, it is apt to retain a small portion of the precipitant. To ascertain the true quantity of this earth, it must, therefore, be re-dissolved in acetous acid, again precipitated by solution of pure ammonia, dried, and ignited.

(*b*.) The oxides (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 oxides 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 307.

(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 pure silver, set in one of earthenware of a larger size, the interstice being filled with sand; and add a little water†. The crucible, covered with a lid, must then

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* Mr. Klaproth procured crystals of alum from one fourth of a grain of alumine. The quantity of alumine he estimates at one tenth the weight of the crystallized alum which is obtained.

† Klaproth effected the disintegration of corundum (which resisted eleven successive fusions with alkali) by adding to the powdered stone, in a crucible, a solution of pure potash, boiling to dryness, and pushing the mixture to fusion. The alkali must be perfectly caustic, and must have been purified by alcohol, as recommended page 82. A platina crucible is unfit for this purpose, as it is corroded by pure alkalies.

be gradually heated; and, as the materials swell and would boil over, they are to be stirred constantly with a rod or spatula of silver. 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 oxide of iron is announced; a bright green indicates manganese, especially if the colour be imparted to water; and a yellowish green the oxide of chrome.

(*a.*) The disintegration of stones, consisting chiefly of alumine, is not easily effected, however, by means of potash, Mr. Chenevix found (Phil. Trans. 1802) that minerals of this class are much more completely decomposed by fusion with calcined borax. One part of the mineral to be examined, reduced to very fine powder, and mingled with 2½ or 3 times its weight of glass of borax (see ch. xvi.), is to be exposed to a strong heat for two hours in a crucible of platina, set in a larger earthen one, and surrounded by sand. The crucible, and its contents, which adhere very strongly to it, are then to be digested, for some hours, with muriatic acid, by which a perfect solution will be accomplished. The whole of the earthy part is then to be precipitated by sub-carbonate of ammonia; and the precipitate, after being well washed, is to be re-dissolved in muriatic acid. By this means, the borax is separated. The analysis is afterwards to be conducted nearly in the manner which will presently be described.

(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 oxide of manganese. (See Klaproth, i. 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 alkali. 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 contain 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 oxide 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 oxide 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 liqour must be heated during a few minutes. Let the precipitate, occasioned by the alkali, 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 strontities; besides metallic oxides, 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 alkali 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 phospate 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, chap. xvii.

(S.) The method of separating, from each other, the metallic oxides, 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 oxides thus obtained, if insoluble in dilute nitric or muriatic acid, will be rendered soluble, 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 308.

The oxides 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 oxides dissolved by an acid, add a solution of crystallized carbonate of potash, as long as any precipitation ensues. This will separate the oxides of iron, chrome, and nickel; but the oxide of manganese and the magnesia, if any be present, will remain dissolved.

If a small quantity of oxide of manganese be suspected in an oxide of iron, it may be detected by mixing the oxide 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 oxide of manganese may be separated by adding to their solution (*c*) the hydro-sulphuret of potash (see ch. iii. sec. 6.), 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 oxide 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 oxides. From this combination with potash the chromic oxide 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 oxide of chrome will fall down, because the quantity of oxygen, required for its acidification, has been separated by the muriatic acid.

(*f*.) The oxides 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 oxide of iron will be precipitated, and must be dried and weighed. If highly oxydized, it must, before weighing, be calcined with wax, in a crucible. The oxide 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 com-

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* For an example of the separation of nickel from iron, see Klaproth, vol. i. p. 422; where, also, and page 428, is an instance of the testing of nickel for copper.

ponent 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 similar 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 alkali, 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 alkali 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 alkali; 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.) Zircon may be separated from alumine, by boiling the mixed earths with pure soda, which acts only on the latter. (Klaproth, vol. ii. p. 213.) From an acid solution containing both earths, the alumine is thrown down by a saturated carbonate of potash, which, when added in excess, re-dissolves the zircon. Glucine and zircon, or glucine and yttria, may be separated, when mixed together in solution, by prussiate of potash, which has no action on glucine, but precipitates the two other earths.

(V.) To separate yttria from alumine, precipitate them from a solution containing both earths, by pure ammonia; boil the precipitate in a solution of pure soda, which chiefly takes up alumine; neutralize the solution with sulphuric acid, and add carbonate of soda to the solution, brought to the boiling temperature. A precipitate will ensue, consisting of alumine, with some yttria. To separate the latter earth, dissolve in muriatic acid, and add an excess of carbonate of ammonia, which takes up only the yttria. To ensure, still farther, the purity of the alumine, dissolve the residue in an excess of sulphuric acid: add a small portion of sulphate of potash, and crystallize the solution. The crystals of alum, that are produced, contain 1-10th of alumine.

(W.) 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 alkali.

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, re-dissolve 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 potash, should the latter alkali 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 alkali 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, enumerated in the first chapter of Part II. (Sec. 2.)

X. 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 125.

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. Both the fixed alkalies have since been frequently discovered in native minerals; viz. soda in basalt (Klaproth, ii. 195); in pitch-stone (207); and in kling-stone, amounting to 8 per cent. (182). The same skilful analyst has found potash in Hungarian pearl-stone (263); and, accompanied by soda, in pumice (20).

A new method has lately been proposed by Mr. Davy (Phil. Trans. 1805, or Nich. Journ. xiii. 86.), for analyzing stones, containing either of the fixed alkalies; viz. by means of the boracic acid. The process is sufficiently simple. One hundred grains of the stone to be examined must be fused, during half an hour, at a strong red-heat, with 200 grains of boracic acid. An ounce and half of nitric acid, diluted with 7 or 8 parts of water, must be digested on the mass, till the whole has been decomposed. The fluid must be evaporated, till its quantity is reduced to an ounce and half, or two ounces.

If the stone contain silex, this earth will be separated in the process of solution and evaporation. It must be collected on a filter, and washed well with water, till the boracic acid, and all the saline matter are separated. The fluid, and all that has passed through the filter, must be evaporated to about half a pint; then saturated with carbonate of ammonia; and boiled with an excess of that salt, till all the materials that it contains, capable of being precipitated, have fallen to the bottom of the vessel. The solution must then be passed through a filter, which retains the earths and metallic oxides. It must then be mixed with nitric acid, till it tastes strongly sour, and evaporated till the boracic acid appears free. The fluid must next be evaporated to dryness; when by exposure to a heat of 450° Fahrenheit, the nitrate of ammonia will be decomposed, and the nitrate of potash or soda will remain in the vessel.

The remaining earths and metallic oxides are separated from each other by common processes; viz. alumine by solution of potash; lime by sulphuric acid; oxide of iron by succinate of ammonia; oxide of manganese by hydro-sulphuret of potash; and magnesia by pure soda.

2. *Table of 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.
    - silex, H. a.
    - metallic oxides, H. a.
    - glucine, T.
- *Barytes and Strontites* from other earths, B.
  - from strontites, C.
- *Chrome* from manganese, &c. S. c.
  - iron and nickel, S. e.
- *Earths* from oxides, D.
- *Glucine* from alumine, T.
- *Iron* from manganese, S. e.
  - nickel, S. f.
- *Lime* from magnesia, F.
  - alumine, E. b.
  - its quantity, F.

Magnesia from lime, F.
alumine, G.
manganese, S. d.
its quantity, F.
Manganese, indications of, M.
from iron, chrome, and nickel, S. c.
from magnesia, S. d.
Nickel from manganese, S. e.
iron, S. f.
Oxides, metallic, from earths, D.
Potash from earths and oxides, W.
Silex from alumine, H. a.
earths in general, O. c.
oxides, H. b.
Soda from earths and oxides, X.
Strontites, see *Barytes*.
Yttria from alumine, &c. V.
Zircon from alumine, &c. U.

SECTION V.

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 alkali.

Impure sulphur, consumed by burning in a small crucible, leaves a residue of oxide of iron and silex.

II. *Coals*.

1. The proportion of bituminous matter in coal may be learnt by distillation, in an earthen retort, and collecting their 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 powder, 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 alkalize the nitre. Thus, since 12.709 of carbon are required to alkalize 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 oxide 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.

SECTION VI.

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. Ores of the same metal, also, as the mineralizing ingredients vary, require very different treatment. 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. If sulphur, however, be present in an ore, which may be generally known by its external characters, as described by mineralogical writers, it impedes the action of acids; and should be separated, either by roasting the ore on a muffle, or by projecting it, mixed with twice or thrice its weight of nitre into a red-hot crucible, washing off the alkali afterwards by hot water.

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.

1. *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 muriate of tin will show the presence of gold by a 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, palladium, silver, and mercury.

2. 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 contains 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, i. p. 554, &c.

3. *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, vol. i. 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.

4. *Iron ores* may be dissolved in dilute muriatic acid, or, if the metal be too highly oxydized 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 oxides of iron, manganese, and zinc. It may be precipitated by carbonate of soda, which will separate them all. The oxide of zinc will be taken up by a solution of pure ammonia; distilled vinegar will take up the manganese, and will leave the oxide 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.

5. *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 alkaline solution with muriatic acid, which will throw down an oxide of tin. Let this be re-dissolved by an excess of muriatic acid; again precipitated by carbonate of soda; and, being dried and weighed, let it, after lixiviation, be once more dissolved in muriatic acid. The insoluble part consists 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.

6. *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.

7. *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.

8. *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 oxide 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 alkali will retain the oxide of zinc. This may be separated by the addition of an acid, or by the evaporation of the solvent.

9. *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 oxide 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, i. p. 560.

10. *Ores of arsenic* may be digested with nitro-muriatic acid, composed of one part nitric, and one and a half or two of muriatic acids. 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.

11. *Ores of bismuth* are also assayed by digestion in nitric acid moderately diluted. The addition of water precipitates the oxide, 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, i. p. 554; Mode of detecting a small Quantity of Silver in Bismuth, ditto, p. 220. c.

12. *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 oxide 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 chap. xix. sect. 18. An example of the analysis of an ore of cobalt may be seen in Klaproth, i. p. 564; and of sulphate of cobalt, p. 579.

13. *Ores of nickel.* Dissolve them in nitric acid, and add to the solution pure ammonia, in such proportion that the alkali may be considerably in excess. This will precipitate other metals, and will retain the oxide of nickel in solution, which may be obtained by evaporation to dryness, and heating the dry mass till the nitrate of ammonia has sublimed.

14. *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 oxydized manganese. The ore may afterward be digested with strong muriatic acid, which will take up the oxide of manganese. Oxygenized 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 oxide, which becomes black when heated in a crucible. Ores, suspected to contain manganese, may also be distilled *per se*, or with sulphuric acid, when oxygen gas will be obtained. Oxide of manganese may be separated from oxide of iron by solution of pure potash, which takes up the former but not the latter. See the analysis of an ore of manganese, *via humida*, in Klaproth i. 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 chap. xviii. sect. 19.

15. *Ores of uranium.* These may be dissolved in dilute nitric acid, which takes up the uranitic oxide, 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 oxide of zinc and uranium. The former may be separated by digestion in pure ammonia, which leaves, undissolved, the oxide of uranium. 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 uranium, and which, on evaporation, will therefore separate first.

16. *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 oxide, distinguishable, by its becoming white on the addition of liquid ammonia, from the oxide of uranium. To reduce this oxide to tungsten, 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.

17. *Ores of molybdena.* Repeated distillation to dryness, with nitric acid, converts the oxide 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, vol. i. p. 534, 538.)

Respecting the ores of the remaining metals, sufficient information has been already given for the purposes of the general student, in part i. chap. xviii. of this work; and they are of such rare occurrence, that it is unnecessary to describe them more in detail. It may be proper, however, to state where the best examples of the analysis of each may be found.

18. *Ores of titanium.* Consult Gregor in *Journ. de Physique*, xxxix. 72. 152; Klaproth, i. 496; and Chenevix, Nich. Journ. v. 132.

19. *Ores of tellurium.* See Klaproth, ii. 1.

20. *Ores of tantalium.* *Ann. de Chim.* xliii. 276.

21. *Ores of chromium.* Vauquelin, *Ann. de Chim.* xxv.

22. *Ores of columbium.* Hatchett, Phil. Trans. 1802.

23. *Ores of palladium and rhodium.* Wollaston, Phil. Trans. 1805.

24. *Ores of iridium and osmium.* Tennant, Phil. Trans. 1804.

25. *Ores of cerium.* Hisenger and Berzelius, and Vauquelin, Nich. Journ. xii.

SECTION VII.

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 extensive strata, a more complicated apparatus is required.—An assaying furnace, with muffles, crucibles, &c. are absolutely necessary. These have already been enumerated in the chapter on Apparatus, and will be again described in the Explanation of the Plates.

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 oxide 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 alkaline 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 those fluxes that are most generally applicable.

The *black flux* is formed, by setting fire to a mixture of one part of nitrate of potash, and two of acidulous tartrite of potash; which affords an intimate mixture of sub-carbonate of potash, with a fine light coal. *White flux* is obtained by projecting into a red-hot crucible, equal parts of the same salts. Two parts of muriate of soda, previously dried in a crucible, one part of dry and 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 and finely sifted 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 metal is found at the bottom of the crucible, in the form of a round button.

The volatile metals, as mercury, zinc, arsenic, tellurium, and osmium, it is obvious, ought not to be treated in the above manner, and require to be distilled with inflammable matters in an earthern 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; and, for various excellent examples, to the essays of Vauquelin, in the *Annales de Chimie;* to those of Mr. Hatchett and Mr. Chenevix, in the *Philosophical Transactions;* of Dr. Kennedy, in *Nicholson's Journal;* and of Mr. Klaproth, in the work already frequently referred to. It is only, indeed, by an attention to these, and a few other models of chemical skill and accuracy, conjoined with the practical imitation of them, that facility, or certainty, in the art of analyzing minerals can be acquired: and though general rules are, in this instance, of considerable utility, it is impossible to frame any that can be adapted to the infinite variety which nature presents in the productions of the mineral kingdom.

PART III.

APPLICATION OF CHEMICAL TESTS AND RE-AGENTS TO VARIOUS USEFUL PURPOSES.

CHAPTER I.

METHOD OF DETECTING POISONS.

When sudden death is suspected to have been occasioned by the administration of poison, either wilfully or by accident, the testimony of the physician is occasionally required to confirm or invalidate this suspicion. 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.

SECTION I.

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

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* I use the term arsenic, instead of the more proper one, arsenous acid; and corrosive sublimate, for muriate of mercury; because the former terms are more generally understood.

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. 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 sulotion of sulphate of copper. The presence of arsenic will be manifested by a yellowish-green precipitate; or boil a portion of the suspected powder with a dilute solution of pure potash, and with this precipitate the sulphate of copper, when a similar appearance will ensue still more remarkably, if arsenic be present. The colour of this precipitate is perfectly characteristic. It is that of the pigment called Scheele's green. (See chap. xviii. sect. 17.) To identify the arsenic with still greater certainty, it may be proper, at the time of making the experiments on a suspected substance, to perform similar ones, as a standard of comparison, on what is actually known to be arsenic. Let the colour, therefore, produced by adding an alkaline solution of the substance under examination, to a solution of sulphate of copper, be compared with that obtained by a similar admixture of a solution of copper with one of real arsenic in alkali.

(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 222); or if this cannot be procured, with two parts of very 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 and dry. 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 a low red-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 oxide of arsenic, 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 oxide; 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.).

SECTION II.

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 alkali, 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, or sulphate of soda. 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.

SECTION III.

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.

I. 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 alkali must be added as is more than sufficient to saturate the acid.

II. 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. Acetate 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.

The competency of this method, however, to the discovery of very minute quantities of lead, has been lately set aside by the experiments of Dr. Lambe*, the author of a skilful analysis of the springs of Lemington Priors, near Warwick. By new methods of examination, he has detected the presence of lead in several spring-waters, that manifest no change on the addition of the sulphuretted test ; and has found that metal in the precipitate, separated from such waters by the carbonate of potash or soda. In operating on these waters, Dr. Lambe noticed the following appearances.

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* See his " Researches into the Properties of Spring Water." 8vo. London. Johnson. 1803.

(*a.*) The test forms sometimes a dark cloud, with the precipitate effected by alkalies, which has been re-dissolved in nitric acid.

(*b.*) Though it forms, in other cases, no cloud, the precipitate itself becomes darkened by the sulphuretted test.

(*c.*) The test forms a white cloud, treated with the precipitate as in (*a*). These two appearances may be united.

(*d.*) The test neither forms a cloud, nor darkens the precipitate.

(*e.*) In the cases (*b*), (*c*), (*d*), heat the precipitate, in contact with an alkaline carbonate, to redness; dissolve out the carbonate by water; and treat the precipitate as in (*a*). The sulphuretted test then forms a dark cloud with the solution of the precipitate. In these experiments, it is essential that the acid, used to re-dissolve the precipitate, shall not be in excess; and if it should so happen, that excess must be saturated before the test is applied. It is better to use so little acid, that some of the precipitate may remain undissolved.

(*f.*) Instead of the process (*e*) the precipitate may be exposed without addition, to a red-heat, and then treated as in (*a*). In this case, the test will detect the metallic matter; but with less certainty than the foregoing one.

The nitric acid, used in these experiments, should be perfectly pure; and the test should be recently prepared, by saturating water with sulphuretted hydrogen gas.

Another mode of analysis, employed by Dr. Lambe, consists in precipitating the lead by muriate of soda; but as muriate of lead is partly soluble in water, this test cannot be applied to small portions of suspected water. The precipitate must be, therefore, collected from two or three gallons, and heated to redness with twice its weight of carbonate of soda. Dissolve out the soda; add nitric acid, saturating any superfluity; and then apply the sulphuretted test.

The third process, which is the most satisfactory of all, and is very easy, except for the trouble of collecting a large quantity of precipitate, is the actual reduction of the metal, and its exhibition in a separate form. The precipitate may be mixed with its own weight of alkaline carbonate, and exposed either with or without the addition of a small proportion of charcoal, to heat sufficient to melt the alkali. On breaking the crucible, a small globule of lead will be found reduced at the bottom. The precipitate from about fifty gallons of water yielded Dr. L. about two grains of lead.

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 vial, sixteen grains of sulphuret of lime, prepared in the dry way (by exposing to a red-heat, in a covered crucible, equal weights of powdered lime and sulphur, accurately mixed), and 20 grains of acidulous tartrite of potash (cream of tartar). The vial 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 further proof of the presence of lead in wines is the occurrence of a precipitate on adding a solution of the sulphate of soda.

The quantity of lead, which has been detected in sophisticated wine, may be estimated at forty grains of the metal in every fifty gallons. (Lambe, p. 175.)

When a considerable quantity of acetate 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.

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. (Systême, vol. i. p. 240.)

CHAPTER 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 occur, on dilution, it is a proof of the presence of sulphate of lead or of lime.

Iron may 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 chap. xi. sec. 4.

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 will 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 at least 1170.

4. *Acetic Acid,—Acidum Acetosum, P. L.—Radical or concentrated Vinegar.*

This acid is often contaminated by sulphurous 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 sulphurous 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 1060 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. (See the preceding chapter.)

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 adultered, 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 re-dissolved 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 tartarous acid ; and at others with muriate of ammonia.

Sulphuric acid is detected by solutions of barytes ; tartarous 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. *Sub-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 mixtures 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 18 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 afterwards nitrate of silver, to ascertain the presence of muriatic acid. Carbonate of potash will be shown by a precipitate ensuing on the addition of tartarous acid to a strong solution of the alkali; for, this acid forms a difficultly soluble salt with potash, but not with soda.

13. *Solution of Carbonate of Ammonia,—Aqua Ammoniæ 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 alkali, 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 alkali, 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 alkali ; the alkali 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 Fahrenheit, 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 alkali, both of which may be detected by the vegetable infusions, page 281. 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 a 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 308.

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. *Acetate of Potash,—Kali Acetatum, P. L.*

Genuine acetate of potash is perfectly soluble in four times its weight of alcohol, and may thus be separated 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 acetate 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 when it is about to crystallize. The fraud may be discovered very readily if the salt consists 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 100 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 alkali 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 acetate 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. *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. *Sub-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 1-32d 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.

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 oxide, on long exposure to the air; by its adhesion to the surface of glass; and, when shaken with water in a bottle, by the speedy 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 oxydize that metal. Pour off the water, and digest the mercury with a little acetous acid. This will dissolve the oxide of lead, which will be indicated by a blackish precipitate with sulphuretted water. Or, to this acetous solution, add a little sulphate of soda,

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* Prepared by digesting a little verdegris in the solution of pure ammonia.

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 mercury, it may be detected by solution in nitric acid and the addition of sulphuretted 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 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 Oxide 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 Oxide 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 sulphuretted 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 Oxide 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 oxide of lead may be discovered as in the last article; and chalk, by adding to the dilute solution a little oxalic acid.

37. *Red Sulphuretted Oxide 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

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* See Mr. Accum's valuable papers on the detection of adulterations, in Nicholson's Journal, 4to.

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 Sulphuretted Oxide 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 alkali to extract the sulphur, and afterwards exposing the residuum to heat, which ought entirely to evaporate.

39. *Yellow Oxide or Sub-Sulphate 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.

The watery solution of lunar caustic, when mingled with one of common salt, should give a copious curdy precipitate.

41. *White Oxide of Zinc,—Zincum Calcinatum, P. L.—Flowers of Zinc.*

Oxide 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, sulphuretted water, or sulphuret of ammonia. Arsenic, to which the activity of this medicine has been sometimes ascribed, is detected, also, by sulphuretted 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 Oxide 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 boiling distilled vinegar.

43. *Acetate of Lead,—Cerussa Acetata, P. L.—Sugar of Lead.*

If the acetate of lead should be adulterated with acetate 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. Acetate of lead ought to dissolve entirely in water, and any thing that resists solution may be regarded as an impurity.

44. *Green Oxide, or Sub-acetate of Copper,—Verdegris.*

This substance 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 amount. 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 Acetate of Copper,—Distilled or Crystallized Verdegris.*

This is prepared by dissolving the common verdegris in distilled vinegar, and crystallizing the solution. These caystals 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 acetate 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 alkali. 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 800 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.

49. *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 the 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.

CHAPTER III.

USE OF CHEMICAL RE-AGENTS TO CERTAIN ARTISTS AND MANUFACTURERS.

To point out all the beneficial applications of chemical substances 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 Potashes, Pearl-ashes, and Barilla.*

Few objects of commerce are sophisticated to a greater extent than the alkalies, 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 the work (see p. 104) 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 Alkaline Substances used in Bleaching;"—see Transactions of the Irish Academy for 1789.

"To discover whether any quantity of fixed alkali worthy of 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 alkali 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 alkali, the above trial is in general superfluous, except for the purpose of detecting lime. The quantity of alkali 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 alkaline 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 alkaline 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 percipitate on a paper-filter, placed in a glass funnel. The percipitated 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 alkali of that particular species which is contained in one ounce of the substance examined; all beside is superfluous matter.

"I have said, that alkalies of the *same species* may thus be directly compared, because alkalies of *different* species cannot but require the intervention of another proportion; and the reason is, because *equal* quantities of alkalies of different species precipitate unequal quantities of earth of alum: Thus 100 parts, by weight, of mere vegetable alkali precipitate 78 of earth of alum, but 100 parts of *mineral* alkali 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 alkali, denotes of the mineral alkali. Hence the quantities of alkali 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 alkali; 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 alkali. But kelps and pot-ashes, as they contain different sorts of alkali, 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 artists, 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, 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 oxide.

From an observation of Klaproth (Essays, i. p. 572), it appears that oxides of iron and manganese are separable by nitrous acid with the addition of sugar, which takes up the manganese only.

CHAPTER 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 the 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.

SECTION I.

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 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 limestones, 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 neighboured 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 tea-cup 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 lime-stone 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.

SECTION II.

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.

SECTION III.

Analysis of Soils.

The following rules, for determining the composition of a soil, are copied from a Memoir, presented by Mr. Davy to the Board of Agriculture.

I. *Utility of Investigations relating to the Analysis of Soils.*

The methods of improving lands are immediately connected with the knowledge of the chemical nature of soils, and experiments on their composition appear capable of many useful applications.

The importance of this subject has been already felt by some very able cultivators of science; many useful facts and observations, with regard to it, have been furnished by Mr. Young; it has been examined by Lord Dundonald, in his treatise on the Connexion of Chemistry with Agriculture, and by Mr. Kirwan in his excellent essay on Manures; but the inquiry is still far from being exhausted, and new methods of elucidating it are almost continually offered, in consequence of the rapid progress of chemical discovery.

In the following pages I shall have the honour of laying before the Board, an account of those methods of analysing soils which appear most precise and simple, and most likely to be useful to the practical farmer; they are founded partly upon the labours of the gentlemen, whose names have been just mentioned, and partly upon some later improvements.

II. *Of the Substances found in Soils.*

The substances which are found in soils, are certain mixtures or combinations of some of the primitive earths, animal and vegetable matter in a decomposing state, certain saline compounds, and the oxide of iron. These bodies always retain water, and exist in very different proportions in different lands; and the end of analytical experiments is the detection of their quantities and mode of union.

The *earths* found in common soils are principally silex, or the earth of flints, alumine, or the pure matter of clay, lime, or calcareous earth, and magnesia.

Silex, or the earth of flints, when perfectly pure, appears in the form of a white powder, which is incombustible, infusible, insoluble in water, and not acted upon by common acids; it is the substance which constitutes the principal part of rock crystal; it composes a considerable part of hard gravelly soils, of hard sandy soils, and of hard stony lands.

Alumine, or pure clay, in its perfect state is white like silex; it adheres strongly to the tongue, is incombustible, insoluble in water, but soluble in acids, and in fixed alkaline menstrua. It abounds most in clayey soils and clayey loams; but even in the smallest particles of these soils it is usually united to silex and oxide of iron.

Lime is the substance well known in its pure state under the name of quick lime. It always exists in soils in combination, and that principally with fixed air or carbonic acid, when it is called carbonate of lime; a substance which in the most compact form constitutes marble, and in its looser form chalk. Lime, when combined with sulphuric acid (oil of vitroil), produces sulphate of lime (gypsum), and with phosphoric acid, phosphate of lime. The carbonate of lime, mixed with other substances, composes chalky soils and marls, and it is found in soft sandy soils.

Magnesia, when pure, appears as white, and in a lighter powder, than any of the other earths; it is soluble in acid, but not in alkaline menstrua; it is rarely found in soils; when it does exist, it is either in combination with carbonic acid, or with silex and alumine.

Animal decomposing matter exists in very different states, according as the substances from which it is produced are different; it contains much carbonaceous substance; and may be principally resolved by heat into this substance, volatile alkali, inflammable aeriform products, and carbonic acid; it is principally found in lands that have been lately manured.

Vegetable decomposing matter is likewise very various in kind, it contains usually more carbonaceous substance than animal matter, and differs from it in the results of its decomposition, principally in not producing volatile alkali; it forms a great proportion of all peats; it abounds in rich mould, and is found in larger or smaller quantities in all lands.

The *saline compounds* found in soils are very few, and in quantities so small, that they are rarely to be discovered. They are principally muriate of soda (common salt), sulphate of magnesia (Epsom salt), and muriate and sulphate of potash, nitrate of lime, and the mild alkalies.

The *oxide of iron* is the same with the rust produced by exposing iron to the air and water; it is found in all soils, but is most abundant in yellow and red clays, and in yellow and red siliceous sands.

A more minute account of these different substances would be incompatible with the object of this paper. A full description of their properties and agencies may be found in the elementary books on chemistry, and particularly in the System of Chemistry by Dr. Thomson (2d edit.); and in Henry's Epitome of Chemistry.

III. *Instruments required for the Analysis of Soils.*

The really important instruments required for the analysis of soils are few, and but little expensive. They are a balance capable of containing a quarter of a pound of common soil, and capable of turning when loaded, with a grain; a series of weights from a quarter of a pound Troy to a grain; a wire sieve, sufficiently coarse to admit a pepper corn through its apertures; an Argand lamp and stand; some glass bottles; Hessian crucibles; porcelain, or queen's ware evaporating basons; a Wedgewood pestle and mortar; some filters made of half a sheet of blotting-paper, folded so as to contain a pint of liquid, and greased at the edges; a bone knife, and an apparatus for collecting and measuring aeriform fluids.

The chemical substances, or re-agents required for separating the constituent parts of the soil, are muriatic acid (spirit of salt), sulphuric acid, pure volatile alkali dissolved in water, solution of prussiate of potash, soap lye, solution of carbonate of ammoniac, of muriate of ammonia, solution of neutral carbonate of potash, and nitrate of ammoniac. An account of the nature of these bodies, and their effects, may be found in the chemical works already noticed; and the re-agents are sold, together with the instruments mentioned above, by Mr. Knight, Foster-lane, Cheapside, arranged in an appropriate chest.

IV. *Mode of collecting Soils for Analysis.*

In cases when the general nature of the soil of a field is to be ascertained, specimens of it should be taken from different places, two or three inches below the surface, and examined as to the similarity of their properties. It sometimes happens, that upon plains the whole of the upper stratum of the land is of the same kind, and in this case, one analysis will be sufficient; but in valleys, and near the beds of rivers, there are very great differences, and it now and then occurs that one part of a field is calcareous, and another part siliceous; and in this case, and in analogous cases, the portions different from each other should be separately submitted to experiment.

Soils when collected, if they cannot be immediately examined, should be preserved in vials quite filled with them, and closed with ground glass stoppers.

The quantity of soil most convenient for a perfect analysis, is from two to four hundred grains. It should be collected in dry weather, and exposed to the atmosphere till it becomes dry to the touch.

The specific gravity of a soil, or the relation of its weight to that of water, may be ascertained by introducing into a vial, which will contain a known quantity of water, equal volumes of water and of soil; and this may be easily done by pouring in water till it is half full, and then adding the soil till the fluid rises to the mouth; the difference between the weight of the soil and that of the water, will give the result. Thus if the bottle contains four hundred grains of water, and gains two hundred grains when half filled with water and half with soil, the specific gravity of the soil will be 2, that is, it will be twice as heavy as water, and if it gained one hundred and sixty-five grains, its specific gravity would be 1825, water being 1000.

It is of importance, that the specific gravity of a soil should be known, as it affords an indication of the quantity of animal and vegetable matter it contains; these substances being always most abundant in the lighter soils.

The other physical properties of soils should likewise be examined before the analysis is made, as they denote, to a certain extent, their composition, and serve as guides in directing the experiments. Thus siliceous soils are generally rough to the touch, and scratch glass when rubbed upon it; aluminous soils adhere strongly to the tongue, and emit a strong earthy smell when breathed on; and calcareous soils are soft, and much less adhesive than aluminous soils.

V. *Mode of ascertaining the Quantity of Water of Absorption in Soils.*

Soils, though as dry as they can be made by continued exposure to air, in all cases still contain a considerable quantity of water, which adheres with great obstinacy to the earths and animal and vegetable matter, and can only be driven off from them by a considerable degree of heat. The first process of analysis is, to free the given weight of soil from as much of this water as possible, without in other respects affecting its composition; and this may be done by heating it for ten or twelve minutes over an Argand's lamp, in a bason of porcelain, to a temperature equal to 300 * Fahrenheit; and in case a thermometer is not used, the proper degree may be easily ascertained, by keeping a piece of wood in contact with the bottom of the dish; as long as the colour of the wood remains unaltered, the heat is not too high; but when the wood begins to be charred, the process must be stopped. A small quantity of water will perhaps remain in the soil even after this operation, but it always affords useful comparative results; and if a higher temperature were employed, the vegetable or animal matter would undergo decomposition, and in consequence the experiment be wholly unsatisfactory.

The loss of weight in the process should be carefully noted; and when in four hundred grains of soil it reaches as high as 50, the soil may be considered as in the greatest degree absorbent,

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* In several experiments, in which this process has been carried on by distillation, I have found the water that came over pure, and no sensible quantity of other volatile matter was produced.

and retentive of water, and will generally be found to contain a large proportion of aluminous earth. When the loss is only from 20 to 10, the land may be considered as only slightly absorbent and retentive, and the siliceous earth as most abundant.

VI. *Of the Separation of Stones, Gravel, and vegetable Fibres, from Soils.*

None of the loose stones, gravel, or large vegetable fibres should be divided from the pure soil till after the water is drawn off; for these bodies are themselves often highly absorbent and retentive, and in consequence influence the fertility of the land. The next process, however, after that of heating, should be their separation, which may be easily accomplished by the sieve, after the soil has been gently bruised in a mortar. The weights of the vegetable fibres or wood, and of the gravel and stones, should be separately noted down, and the nature of the last ascertained; if calcareous, they will effervesce with acids; if siliceous, they will be sufficiently hard to scratch glass; and if of the common aluminous class of stones, they will be soft, easily scratched with a knife, and incapable of effervescing with acids.

VII. *Separation of the Sand and Clay, or Loam, from each other.*

The greater number of soils, besides gravel and stones, contain larger or smaller proportions of sand of different degrees of fineness; and it is a necessary operation, the next in the process of analysis, to detach them from the parts in a state of more minute division, such as clay, loam, marl, and vegetable and animal matter. This may be effected in a way sufficiently accurate, by agitation of the soil in water. In this case, the coarse sand will generally separate in a minute, and the finer in two or three minutes, whilst the minutely divided earthy, animal, or vegetable matter, will remain in a state of mechanical suspension for a much longer time; so that, by pouring the water from the bottom of the vessel, after one, two, or three minutes, the sand will be principally separated from the other substances, which, with the water containing them, must be poured into a filter, and after the water has passed through, collected, dried, and weighed. The sand must likewise be weighed, and their respective quantities noted down. The water of lixiviation must be preserved, as it will be found to contain the saline matter, and the soluble animal or vegetable matters, if any exist in the soil.

VIII. *Examination of the Sand.*

By the process of washing and filtration, the soil is separated into two portions, the most important of which is generally the finely divided matter. A minute analysis of the sand is seldom or never necessary, and its nature may be detected in the same manner as that of the stones or gravel. It is always either siliceous sand, or calcareous sand, or a mixture of both. If it consist wholly of carbonate of lime, it will be rapidly soluble in muriatic acid, with effervescence; but if it consist partly of this substance, and partly of siliceous matter, the respective quantities may be ascertained by weighing the residuum after the action of the acid, which must be applied till the mixture has acquired a sour taste, and has ceased to effervesce. This residuum is the siliceous part: it must be washed, dried, and heated strongly in a crucible; the difference between the weight of it and the weight of the whole, indicates the proportion of calcareous sand.

IX. *Examination of the finely divided Matter of Soils and Mode of detecting mild Lime and Magnesia.*

The finely divided matter of the soil is usually very compound in its nature; it sometimes contains all the four primitive earths of soils, as well as animal and vegetable matter; and to ascertain the proportions of these with tolerable accuracy, is the most difficult part of the subject.

The first process to be performed, in this part of the analysis, is the exposure of the fine matter of the soil to the action of the muriatic acid. This substance should be poured upon the earthy matter in an evaporating bason, in a quantity equal to twice the weight of the earthy matter, but diluted with double its volume of water. The mixture should be often stirred, and suffered to remain for an hour, or an hour and a half, before it is examined.

If any carbonate of lime, or of magnesia, exist in the soil, they will have been dissolved in this time by the acid, which sometimes takes up likewise a little oxide of iron, but very seldom any alumine.

The fluid should be passed through a filter; the solid matter collected, washed with rain water, dried at a moderate heat, and weighed. Its loss will denote the quantity of solid matter taken up. The washings must be added to the solution, which, if not sour to the taste, must be made so by the addition of fresh acid, when a little solution of common prussiate of potash must be mixed with the whole. If a blue precipitate occurs, it denotes the presence of oxide of iron, and the solution of the prussiate must be dropped in till no farther effect is produced. To ascertain its quantity, it must be collected in the same manner as other solid precipitates, and heated red; the result is oxide of iron.

Into the fluid, freed from oxide of iron, a solution of neutralized carbonate of potash must be poured till all effervescence ceases in it, and till its taste and smell indicate a considerable excess of alkaline salt.

The precipitate that falls down is carbonate of lime; it must be collected on the filter, and dried at a heat below that of redness.

The remaining fluid must be boiled for a quarter of an hour, when the magnesia, if any exist, will be precipitated from it, combined with carbonic acid, and its quantity is to be ascertained in the same manner as that of the carbonate of lime.

If any minute proportion of alumine should, from peculiar circumstances, be dissolved by the acid, it will be found in the precipitate with the carbonate of lime, and it may be separated from it by boiling for a few minutes with soap-lye, sufficient to cover the solid matter.—This substance dissolves alumine, without acting upon carbonate of lime.

Should the finely divided soil be sufficiently calcareous to effervesce very strongly with acids, a very simple method may be adopted for ascertaining the quantity of carbonate of lime, and one sufficiently accurate in all common cases.

Carbonate of lime, in all its states, contains a determinate proportion of carbonic acid, *i. e.* about 45 per cent.; so that when the quantity of this elastic fluid, given out by any soil during the solution of its calcareous matter in an acid, is known, either in weight or measure, the quantity of carbonate of lime may be easily discovered.

When the process by diminution of weight is employed, two parts of the acid, and one part of the matter of the soil, must be weighed in two separate bottles, and very slowly mixed together till the effervescence ceases; the difference between their weight before and after the experiment, denotes the quantity of carbonic acid lost; for every four grains and a half of which, ten grains of carbonate of lime must be estimated.

The best method of collecting the carbonic acid, so as to discover its volume, is by the pneumatic apparatus, the construction and application of which is described at the end of this paper. The estimation is, for every ounce-measure of carbonic acid, two grains of carbonate of lime.

X. *Mode of ascertaining the Quantity of insoluble finely divided Animal and Vegetable Matter.*

After the fine matter of the soil has been acted upon by muriatic acid, the next process is to ascertain the quantity of finely divided insoluble animal and vegetable matter that it contains.

This may be done with sufficient precision, by heating it to strong ignition in a crucible over a common fire till no blackness remains in the mass. It should be often stirred with a metallic wire, so as to expose new surfaces continually to the air; the loss of weight that it undergoes denotes the quantity of the substance that it contains destructible by fire and air.

It is not possible to ascertain whether this substance is wholly animal or vegetable matter, or a mixture of both. When the smell emitted during the incineration is similar to that of burnt feathers, it is a certain indication of some animal matter; and a copious blue flame at the time of ignition, almost always denotes a considerable proportion of vegetable matter. In cases when the experiment is needed to be very quickly performed, the destruction of the decomposible substances may be assisted by the agency of nitrate of ammoniac, which, at the time of ignition, may be thrown gradually upon the heated mass, in the quantity of twenty grains for every hundred of residual soil. It affords the principle necessary to the combustion of the animal and vegetable matter, which it causes to be converted into elastic fluids; and is itself at the same time decomposed and lost.

XI. *Mode of separating Aluminous and Siliceous Matter, and Oxide of Iron.*

The substances remaining after the decomposition of the vegetable and animal matter, are generally minute particles of earthy matter, containing usually alumine and silex with combined oxide of iron.

To separate these from each other, the solid matter should be boiled for two or three hours with sulphuric acid, diluted with four times its weight of water; the quantity of the acid should be regulated by the quantity of solid residuum to be acted on, allowing for every hundred grains two drachms, or one hundred and twenty grains of acid.

The substance remaining after the action of the acid, may be considered as siliceous; and it must be separated, and its weight ascertained, after washing and drying in the usual manner.

The alumine and the oxide of iron, if any exist, are both dissolved by the sulphuric acid; they may be separated by carbonate of ammoniac, added to excess; it throws down the alumine, and leaves the oxide of iron in solution, and this substance may be separated from the liquid by boiling.

Should any magnesia and lime have escaped solution in the muriatic acid, they will be found in the sulphuric acid; this, however, is scarcely ever the case; but the process for detecting them and ascertaining their quantities, is the same in both instances.

The method of analysis by sulphuric acid, is sufficiently precise for all usual experiments; but if very great accuracy be an object, dry carbonate of potash must be employed as the agent, and the residuum of the incineration must be heated red for a half hour, with four times its weight of this substance, in a crucible of silver, or of well baked porcelain. The mass obtained must be dissolved in muriatic acid, and the solution evaporated till it is nearly solid; distilled water must then be added, by which the oxide of iron and all the earths, except silex, will be dissolved in combination as muriates. The silex, after the usual process of lixiviation, must be heated red; the other substances may be separated in the same manner as from the muriatic and sulphuric solutions.

This process is the one usually employed by chemical philosophers for the analysis of stones.

XII. *Mode of discovering Soluble Animal and Vegetable Matter, and Saline Matter.*

If any saline matter, or soluble vegetable or animal matter, is suspected in the soil, it will be found in the water of lixiviation used for separating the sand.

This water must be evaporated to dryness in an appropriate dish, at a heat below its boiling point.

If the solid matter obtained is of a brown colour, and inflammable, it may be considered as partly vegetable extract. If its smell, when exposed to heat, be strong and fetid, it contains animal mucilaginous or gelatinous substance; if it be white and transparent, it may be considered as principally saline matter. Nitrate of potash (nitre) or nitrate of lime, is indicated in this saline matter, by its scintillating with a burning coal. Sulphate of magnesia may be detected by its bitter taste; and sulphate of potash produces no alteration in solution of carbonate of ammoniac, but precipitates solution of muriate of barytes.

XIII. *Mode of detecting Sulphate of Lime (Gypsum) and Phosphate of Lime in Soils.*

Should sulphate or phosphate of lime be suspected in the entire soil, the detection of them requires a particular process upon it. A given weight of it, for instance four hundred grains, must be heated red for half an hour in a crucible mixed with one-third of powdered charcoal. The mixture must be boiled for a quarter of an hour, in a half pint of water, and the fluid collected through the filter, and exposed for some days to the atmosphere in an open vessel. If any soluble quantity of sulphate of lime (gypsum) existed in the soil, a white precipitate will gradually form in the fluid, and the weight of it will indicate the proportion.

Phosphate of lime, if any exist, may be separated from the soil after the process for gypsum. Muriatic acid must be digested upon the soil, in quantity more than sufficient to saturate the soluble earths; the solution must be evaporated, and water poured upon the solid matter. This fluid will dissolve the compounds of earths, with the muriatic acid, and leave the phosphate of lime untouched.

It would not fall within the limits assigned to this paper, to detail any processes for the detection of substances which may be accidentally mixed with the matters of soils. Manganese is now and then found in them, and compounds of the barytic earth; but these bodies appear to bear little relation to fertility or barrenness, and the search for them would make the analysis much more complicated without rendering it more useful.

XIV. *Statement of Results and Products.*

When the examination of a soil is completed, the products should be classed, and their quantities added together, and if they nearly equal the original quantity of soil, the analysis may be considered as accurate. It must, however, be noticed, that when phosphate or sulphate of lime are discovered by the independent process XIII., a correction must be made for the general process, by subtracting a sum equal to their weight from the quantity of carbonate of lime, obtained by precipitation from the muriatic acid.

In arranging the products, the form should be in the order of the experiments by which they are obtained.

Thus 400 grains of a good siliceous sandy soil may be supposed to contain

		Grains.
Of water of absorption		18
Of loose stones and gravel, principally siliceous		42
Of undecompounded vegetable fibres		10
Of fine siliceous sand		200
Of minutely divided matter separated by filtration, and consisting of		
Carbonate of lime	25	
Carbonate of magnesia	4	
Matter destructible by heat, principally vegetable	10	
Silex	40	
Alumine	32	
Oxide of iron	4	
Soluble matter, principally sulphate of pot-ash and vegetable extract	5	
Gypsum	3	
Phosphate of lime	2	
		125
Amount of all the products		395
Loss		5

In this instance the loss is supposed small; but in general, in actual experiments, it will be found much greater, in consequence of the difficulty of collecting the whole quantities of the different precipitates; and when it is within thirty for four hundred grains, there is no reason to suspect any want of due precision in the processes.

XV. *This general Method of Analysis may, in many Cases, be much simplified.*

When the experimenter is become acquainted with the use of the different instruments, the properties of the re-agents, and the relations between the external and chemical qualities of soils, he will seldom find it necessary to perform, in any one case, all the processes that have been described. When his soil, for instance, contains no notable proportion of calcareous matter, the action of the muriatic acid IX. may be omitted. In examining peat soils, he will principally have to attend to the operation by fire and air X.; and in the analysis of chalks and loams, he will often be able to omit the experiment by sulphuric acid XI.

In the first trials that are made by persons unacquainted with chemistry, they must not expect much precision of result. Many difficulties will be met with: but, in overcoming them, the most useful kind of practical knowledge will be obtained; and nothing is so instructive in experimental science, as the detection of mistakes. The correct analyst ought to be well grounded in general chemical information; but perhaps there is no better mode of gaining it, than that of attempting original investigations. In pursuing his experiments, he will be continually obliged to learn from books, the history of the substances he is employing or acting upon; and his theoretical ideas will be more valuable in being connected with practical operation, and acquired for the purpose of discovery.

XVI. *On the Improvement of Soils, as connected with the Principle of their Composition.*

In cases when a barren soil is examined with a view to its improvement, it ought, in all cases, if possible, to be compared with an extremely fertile soil in the same neighbourhood, and in a similar situation: the difference given by their analysis would indicate the methods of cultivation; and thus the plan of improvement would be founded upon accurate scientific principles.

If the fertile soil contained a large quantity of sand, in proportion to the barren soil, the process of amelioration would depend simply upon a supply of this substance; and the method would be equally simple with regard to soils deficient in clay or calcareous matter.

In the application of clay, sand, loam, marl, or chalk, to lands, there are no particular chemical principles to be observed; but when quick lime is used, great care must be taken that it is not obtained from the magnesian lime-stone; for in this case, as has been shown by Mr. Tennant, it is exceedingly injurious to land*. The magnesian lime-stone may be distinguished from the common lime-stone by its greater hardness, and by the length of

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* Phil. Trans. for 1799, p. 305. This lime-stone is found abundantly in Yorkshire, Derbyshire, and Somersetshire.

time that it requires for its solution in acids; and it may be analyzed by the process for carbonate of lime and magnesia, IX.

When the analytical comparison indicates an excess of vegetable matter, as the cause of sterility, it may be destroyed by much pulverization and exposure to air, by paring and burning, or the agency of lately-made quick-lime. And the defect of animal and vegetable matter must be supplied by animal or vegetable manure.

XVII. *Sterile Soils in different Climates and Situations must differ in Composition.*

The general indications of fertility and barrenness, as found by chemical experiments, necessarily must differ in different climates, and under different circumstances. The power of soils to absorb moisture, a principal essential to their productiveness, ought to be much greater in warm and dry countries, than in cold and moist ones; and the quantity of fine aluminous earth they contain larger. Soils, likewise, that are situated on declivities, ought to be more absorbent than those in the same climate on plains or in valleys*. The productiveness of soils must likewise be influenced by the the nature of the subsoil, or the earthy or stony strata on which they rest; and this circumstance ought to be particularly attended to, in considering their chemical nature, and the system of improvement. Thus a sandy soil may sometimes owe its fertility to the power of the subsoil to retain water; and an absorbent clayey soil may occasionally be prevented from being barren, in a moist climate, by the influence of a substratum of sand or gravel.

XVIII. *Of the Chemical Composition of fertile Corn Soils in this Climate.*

Those soils that are most productive of corn, contain always certain proportions of aluminous and calcareous earth in a finely divided state, and a certain quantity of vegetable or animal matter.

The quantity of calcareous earth is however very various, and in some cases exceedingly small. A very fertile corn soil from Ormiston, in East Lothian, afforded me, in an hundred parts, only eleven parts of mild calcareous earth; it contained twenty-five parts of siliceous sand; the finely divided clay amounted to forty-five parts. It lost nine in decomposed animal

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* Kirwan, Trans. Irish Academy, vol. v. p. 175.

and vegetable matter, and four in water, and afforded indications of a small quantity of phosphate of lime.

This soil was of a very fine texture, and contained very few stones or vegetable fibres. It is not unlikely that its fertility was in some measure connected with the phosphate; for this substance is found in wheat, oats, and barley, and may be a part of their food.

A soil from the low lands of Somersetshire, celebrated for producing excellent crops of wheat and beans without manure, I found to consist of one-ninth of sand, chiefly siliceous, and eight-ninths of calcareous marl, tinged with iron, and containing about five parts in the hundred of vegetable matter. I could not detect in it any phosphate or sulphate of lime, so that its fertility must have depended principally upon its power of attracting principles of vegetable nourishment from water and the atmosphere*.

Mr. Tillet, in some experiments made on the composition of soils at Paris, found that a soil composed of three-eighths of clay, two-eighths of river sand, and three-eighths of the parings of lime-stone, was very proper for wheat.

XIX. *Of the Composition of Soils proper for bulbous Roots and for Trees.*

In general, bulbous roots require a soil much more sandy, and less absorbent, than the grasses. A very good potatoe soil, from Varfel, in Cornwall, afforded me seven-eighths of siliceous sand; and its absorbent power was so small, that one hundred parts lost only two by drying at 400° Fahrenheit.

Plants and trees, the roots of which are fibrous and hard, and capable of penetrating deep into the earth, will vegetate to advantage in almost all common soils which are moderately dry, and which do not contain a very great excess of vegetable matter.

I found the soil taken from a field at Sheffield-place, in Sussex, remarkable for producing flourishing oaks, to consist of six parts of sand, and one part of clay and finely divided matter; and one hundred parts of the entire soil, submitted to analysis, produced,

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* This soil was sent to me by T. Poole, Esq. of Nether Stowey. It is near the opening of the river Parret into the British Channel; but, I am told, is never overflowed.

Water	3 parts
Silex	54
Alumine	28
Carbonate of lime . .	3
Oxide of iron . . .	5
Decomposing vegetable matter	4
Loss	3

XX. *Advantages of Improvements made by changing the Composition of Earthy Parts of Soils.*

From the great difference of the causes that influence the productiveness of lands, it is obvious, that, in the present state of science, no certain system can be devised for their improvement, independent of experiment; but there are few cases in which the labour of analytical trials will not be amply repaid by the certainty with which they denote the best methods of amelioration; and this will particularly happen, when the defect of composition is found in the proportions of the primitive earths.

In supplying animal or vegetable manure, a temporary food only is provided for plants, which is in all cases exhausted by means of a certain number of crops; but when a soil is rendered of the best possible constitution and texture, with regard to its earthy parts, its fertility may be considered as permanently established. It becomes capable of attracting a very large portion of vegetable nourishment from the atmosphere, and of producing its crops with comparatively little labour and expense.

Description of the Apparatus for the Analysis of Soils.

Pl. iv. fig. 44.; *a*, *b*, *c*, *d*, *e*, *f*. The different parts of the apparatus required for measuring the quantity of elastic fluid given out during the action of an acid on calcareous soils. *a*. Represents the bottle for containing the soil; *b*, the bottle containing the acid, furnished with a stop-cock; *c*, the tube connected with a flaccid bladder; *d*, *f*, the graduated measure; *e*, the bottle for containing the bladder. When this instrument is used, a given quantity of soil is introduced into *a*; *b*, is filled with muriatic acid, diluted with an equal quantity of water; and the stop-cock being closed, is connected with the upper orifice of *a*, which is ground to receive it. The tube *c*, is introduced into the lower orifice of *a*, and the bladder connected with it placed in its flaccid state in *e*, which is filled with water. The graduated measure is placed under the tube of *e*. When the stop-cock of *b* is turned, the acid flows into *a*, and acts upon the soil; the elastic fluid generated passes through *c* into the bladder, and displaces a quantity of water in *e* equal to it in bulk, and this water flows through the tube into the graduated measure; the water in which gives, by its volume, the indication of the proportion of carbonic acid disengaged from the soil; for every ounce-measure of which, two grains of carbonate of lime may be estimated.

CHAPTER V.

MISCELLANEOUS USES OF CHEMICAL RE-AGENTS.

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 five or six 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.

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 alkaline 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 oxygenized muriatic acid (see chap. xiv. sect. 1.), or by that of oxgenized 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 oxygenized acid discharges all printed and dyed colours. A convenient mode of applying the oxygenized 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 sulphurous acid, or by the fumes of burning sulphur.

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.

APPENDIX I.

CONSISTING OF

VARIOUS USEFUL TABLES.

N°. I.

CORRESPONDENCE BETWEEN ENGLISH AND FOREIGN WEIGHTS AND MEASURES.

1. *English Weights and Measures.*

TROY WEIGHT.

Pound.		Ounces.		Drms.		Scruples.		Grains.		Grammes.
1	=	12	=	96	=	288	=	5760	=	372.96
		1	=	8	=	24	=	480	=	31.08
				1	=	3	=	60	=	3.885
						1	=	20	=	1.295
								1	=	0.06475

AVOIRDUPOIS WEIGHT.

Pound.		Ounces.		Drms.		Grains.		Grammes.
1	=	16	=	256	=	7000	=	453.25
		1	=	16	=	437.5	=	28.32
				1	=	27.975	=	1.81

MEASURES.

Gal.		Pints.		Ounces.		Drms.		Cub. Inch.		Litres.
1	=	8	=	128	=	1024	=	231	=	3.78515
		1	=	16	=	128	=	28.875	=	0.47398
				1	=	8	=	1.8047	=	0.02957
						1	=	0.2256	=	0·00396

N. B. The English ale-gallon contains 282 cubical inches.

2. *German.*

71 lbs. or grs. English troy, . . = 74 lbs. or grs. German apothecaries weight.
1 oz. Nuremberg, medic. weight, = 7 dr. 2 sc. 9 gr. English.
1 mark Cologne, ... = 7 oz. 2 dwt. 4 gr. English troy.

3. *Dutch.*

1 lb. Dutch, . = 1 lb. 3 oz. 16 dwt. 7 gr. English troy.
787½ lbs. Dutch, = 1038 lbs. English troy.

4. *Swedish Weights and Measures, used by Bergman and Scheele.*

The Swedish pound, which is divided like the English apothecary, or troy, pound, weighs 6556 grs. troy.

The kanne of pure water, according to Bergman, weighs 42250 Swedish grains, and occupies 100 Swedish cubical inches. Hence the kanne of pure water weighs 48088.719444 English troy grains, or is equal to 189.9413 English cubic inches; and the Swedish longitudinal inch is equal to 1.238435 English longitudinal inches.

From these data, the following rules are deduced:

1. To reduce Swedish longitudinal inches to English, multiply by 1.2384, or divide by 0.80747.

2. To reduce Swedish to English cubical inches, multiply by 1.9. or divide by 0.5265.

3. To reduce the Swedish pound, ounce, dram, scruple, or grain, to the corresponding English troy denomination, multiply by 1.1382, or divide by .8786.

4. To reduce the Swedish kannes to English wine pints, divide by .1520207, or multiply by 6.57805.

5. To reduce Swedish kannes to English wine gallons, multiply by .8225, or divide by 1.2158.

6. The lod, a weight sometimes used by Bergman, is the 32d part of the common Swedish pound of 16 oz. and the 24th part of the pound of 12 oz. Therefore to reduce it to the English troy pound, multiply by .03557, or divide by 28.1156.

5. *Correspondence of English Weights and Measures with those used in France before the Revolution.*

§ 1. WEIGHTS.

The Paris pound, poids de marc of Charlemagne, contains 9216 Paris grains; it is divided into 16 ounces, each ounce into 8 gros, and each gros into 72 grains. It is equal to 7561 English troy grains.

The English troy pound of 12 ounces contains 5760 English troy grains, and is equal to 7021 Paris grains.

The English avoirdupois pound of 16 ounces contains 7000 English troy grains, and is equal to 8538 Paris grains.

To reduce Paris grains to English troy grains, divide by	1.2189
To reduce English troy grains to Paris grains, multily by	
To reduce Paris ounces to English troy, divide by	1.015734
To reduce English troy ounces to Paris, multiply by	

Or the conversion may be made by means of the following tables :

II.—*To reduce French to English troy weight.*

The Paris pound	=	7561	English troy grains.
The ounce	=	472.5625	
The gros	=	59.0703	
The grain	=	.8204	

II.—*To reduce English troy to Paris weight.*

The English troy pound of 12 ounces . . .	=	7021.	Paris grains.
The troy ounce . .	=	585.0833	
The dram of 60 grains .	=	73.1354	
The penny-weight, or denier, of 24 grains . .	=	29.2541	
The scruple of 20 grains	=	24.3784	
The grain . . .	=	1.2189	

III.—*To reduce English avoirdupois to Paris weight.*

The avoirdupois pound of 16 ounces, or 7000 troy grains	=	8538.	Paris grs.
The ounce . .	=	533.6250	

§ 2. LONG AND CUBICAL MEASURES.

To reduce Paris running feet, or inches, into English, multiply by . . . . . English running feet, or inches, into Paris, divide by	1.065977
To reduce Paris cubic feet, or inches, to English multiply by . . . . . . English cubic feet, or inches, to Paris, divide by	1.211278

Or by means of the following tables :

IV.—*To reduce Paris long measure to English.*

The Paris royal foot of 12 inches	=	12.7977	English inches.
The inch	=	1.0665	
The line, or 1-12th of an inch	=	.0888	
The 1-12th of the line .	=	.0074	

V.—*To reduce English long measure to French.*

The English foot . .	=	11.2596	Parish inches.
The inch	=	.9383	
The 1-8th of an inch .	=	.1173	
The 1-10th . . .	=	.0938	
The line, or 1-12th . .	=	.0782	

VI.—*To reduce French cube measure to English.*

The Paris cube foot .	=	1.211278	English cubical feet, or	2093.088384	inches.
The cubic inch	=	.000700		1.211278	

VII.—*To reduce English cube measure to French.*[*]

The English cube foot, or 1728 cubical inches . . . . = 1427.4864 French cubical inches.
The cubical inch . . . . = .8260
The cube tenth . . . . = .0008

§ 3. MEASURE OF CAPACITY.

The Paris pint contains 58.145[†] English cubical inches, and the English wine-pint contains 28.875[‡] cubical inches; or, the Paris pint contains 2.0171082 English pints, and the English pint contains .49617 Paris pints; hence,

To reduce the Paris pint to the English, multiply By 2.0171082
To reduce the English pint to the Paris, divide by 2.0171082

The septier of Paris is 7736 French, or 9370.45 English, cubical inches; and the muid is 92832 French, or 112445.4 English, cubical inches.

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[*] To convert the weight of a French cubic foot, of any particular substance given in French grains, into the corresponding weight of an English cubic foot in English troy grains, multiply the French grains by 0.6773181, and the product is the number of English troy grains contained in an English cubic foot of the same substance.

[†] It is said by Belidor, *Archit. Hydraul.* to contain 31 oz. 64 grs. of water, which makes it 58.075 English inches; but, as there is considerable uncertainty in the determinations of the weight of the French cubical measure of water, owing to the uncertainty of the standards made use of, it is better to abide by Mr. Everard's measure, which was made by the Exchequer standards, and by the proportions of the English and French foot, as established by the French Academy and Royal Society.

[‡] According to Beaumé, the Paris pint contains 32 French ounces of water, at the temperature of 54.5° of Fahrenheit; which would make it equal to 59.729 English cubical inches.

6. *Table, showing the comparison between French and English Grains. (Poid de Marc.)*

French grs. =	English grs.
1	0.8203
2	1.6407
3	2.4611
4	3.2815
5	4.1019
6	4.9223
7	5.7427
8	6.5631
9	7.3835
10	8.203
20	16.407
30	24.611
40	32.815
50	41.019
60	49.223
70	57.427
80	65.631
90	73.835
100	82.03
200	164.07
300	246.11
400	328.15
500	410.19
600	492.23
700	574.27
800	656.31
900	738.35
1000	820.3
2000	1640.7
3000	2461.1
4000	3281.5
5000	4101.9
6000	4922.3
7000	5742.7
8000	6563.1
9000	7383.5
10,000	8203.0

English grs. =	French grs.
1	1.2189
2	2.4378
3	3.6568
4	4.8757
5	6.0947
6	7.3136
7	8.5325
8	9.7515
9	10.9704
10	12.189
20	24.378
30	36.568
40	48.757
50	60.947
60	73.136
70	85.325
80	97.515
90	109.704
100	121.89
200	243.78
300	365.68
400	487.57
500	609.47
600	731.36
700	853.25
800	975.15
900	1097.04
1000	1218.9
2000	2437.8
3000	3656.8
4000	4875.7
5000	6094.7
6000	7313.6
7000	8532.5
8000	9751.5
9000	10970.4
10,000	12189.0

7. *Table, showing the Comparison between French and English Cubical Inches.*

Cubic inches.		Cubic inches.	
French =	English.	English =	French.
1	1.2136	1	0.8239
2	2.4272	2	1.6479
3	3.6408	3	2.4719
4	4.8544	4	3.2958
5	6.0681	5	4.1198
6	7.2817	6	4.9438
7	8.4953	7	5.7677
8	9.7089	8	6.5917
9	10.9225	9	7.4157
10	12.136	10	8.239
20	24.272	20	16.479
30	36.408	30	24.719
40	48.544	40	32.958
50	60.681	50	41.198
60	72.817	60	49.438
70	84.953	70	57.677
80	97.089	80	65.917
90	109 225	90	74.157
100	121.36	100	82.39
200	242.72	200	164.79
300	364.08	300	247.19
400	485.44	400	329.58
500	606.81	500	411 98
600	728.17	600	494.38
700	849.53	700	576.77
800	970.89	800	659.17
900	1092.25	900	741.57
1000	1213.6	1000	823.9
2000	2427.2	2000	1647.9
3000	3640.8	3000	2471.9
4000	4854.4	4000	3295.8
5000	6068.1	5000	4119.8
6000	7281.7	6000	4943.8
7000	8495.3	7000	5767.7
8000	9708.9	8000	6591.7
9000	10922.5	9000	7415.7
10,000	12136.0	10,000	8239.0

8.—*New French Weights and Measures, (calculated by Dr. Duncan.* jun.)

1. Measures of Length: the Metre being at 32°, and the Foot at 62°.

		English Inches.		Mil.	Fur.	Yds.	Feet.	In.
Millimetre	=	.03937						
Centimetre	=	.39371						
Decimetre	=	3.93710						
Metre	=	39.37100						
Decametre	=	393.71000	=	0	0	10	2	9.7
Hecatometre	=	3937.10000	=	0	0	109	1	1
Kilometre	=	39371.00000	=	0	4	213	1	10.2
Mryriometre	=	393710.00000	=	6	1	156	0	6

2. Measures of Capacity.

		Cubic Inches.		English.			
				Tons.	Hogs.	Wine G.	Pints.
Millilitre	=	.06103					
Centilitre	=	.61028					
Decilitre	=	6.10280					
Litre	=	61.02800	=	0	0	0.	2.1133
Decalitre	=	610.28000	=	0	0	2.	5.1352
Hecatolitre	=	6102.80000	=	0	0	26.419	
Kilolitre	=	61028.00000	=	1	0	12.19	
Myriolitre	=	610280.00000	=	10	1	58.9	

3. Measures of Weight.

		English Grains.		Avoirdupois.		
				Poun.	Oun.	Dram.
Milligramme	=	.0154				
Centigramme	=	.1544				
Decigramme	=	1.5444				
Gramme	=	15.4440				
Decagramme	=	154.4402	=	0	0	5.65
Hecatogramme	=	1544.4023	=	0	3	8.5
Kilogramme	=	15444.0234	=	2	3	5
Myriogramme	=	154440.2344	=	22	1	2

9.—*Reduction of the Ounce Measures used by Dr. Priestley to Cubical Inches.*

Ounce Measures.	French Cubical Inches.	English Cubical Inches.
1	1.567	1.898
2	3.134	3.796
3	4.701	5.694
4	6.268	7.592
5	7.835	9.490
6	9.402	11.388
7	10.969	13.286
8	12.536	15.184
9	14.103	17.082
10	15.670	18.980
20	31.340	37.960
30	47.010	56.940
40	62.680	75.920
50	78.350	94.900
60	94.020	113.880
70	109.690	132.860
80	125.360	151.840
90	141.030	170.820
100	156.700	189.800
1000	1567.000	1898.000

10.—*Table, showing the Absolute Weights and Specific gravities of Gases, and the Quantity of each absorbed by Water.*

(Temperature 60° FAHRENHEIT, Barometer 30.)

	KIND OF GAS.	Weight of 100 Cubic Inches in Eng. Grains.	Specific Gravity Standard.			No. of Cubic Inches absorbed by 100 Inches of Water.	
			Water.	Air.			
	Water, ...	. . . .	1000				
	Atmospheric air . . .	31.	1.2279	1000	S. K.		
Simple Gases.	Oxygen gas, . .	34.	1.35	1103	K.	37.	H.
	Ditto ditto, . . .	34.74	1.39	1127	D.		
	Azotic gas, . .	30.535	1.21	985	K.	1.53	H.
	Ditto, ditto, . . .	30.45	1.20	980	D.		
	Hydrogen gas, .	2.613	0.1031	84	K.	1.61	H.
Compound Combustible Gases.	Ammonia, ...	18.16	0.715	585	K.		
	Ditto, ...	18.	0.713	580	D.	47500.	D.
	Hydro-carburet from stagnant water,	20.66	. . .	666	Dal.	1.40	H.
	Ditto from water over ignited charcoal,	14.5	. . .	468	Cr.		
	Ditto from alcohol, .	16.	. . .	516	Cr.		
	Ditto from ether, .	20.	. . .	645	Cr.		
	Ditto from coal, . .	20.2	. . .	650	Dal.		
	Phosphuretted hydrogen,	. . .	. . .	. .	. .	2.14	H.
	Sulphuretted ditto, .	34.286	1.36	1142	K.	108.	H.
	Ditto ditto, ...	38.17	. . .	1231	Th.		
	Olefiant gas, . . .	28.18	. . .	905	Dei.	12.5	Dal.
	Vapour of Alcohol, .	51.5*	. . .	2100	Dal.		
	Ditto of ether, . .	62.1†	. . .	2250	Dal.		
Oxides.	Carbonic oxide, . .	30.	1.185	967	Cr.	2.01	H.
	Nitrous oxide, . .	50.1	1.985	1615	. .	86.	H.
	Nitric oxide, . . .	37.	1.465	1193	K.	5.	H.
	Ditto ditto, . . .	34.3	1.36	1105	D.		
Acid Gases.	Carbonic acid, . . .	46.5	1.84	1500	K.	108.	H.
	Ditto ditto, . . .	45.5	1.802	1470	D.		
	Muriatic acid, . . .	44.7	1.765	1430	B.	51500.	T.
	Ditto ditto, . . .	59.8	. . .	1929	K.		
	Nitric acid, ...	76.	3.	2425	D.		
	Sulphurous, . . .	70.215	2.75	2240	K.	3300.	T.

B. Brisson; Cr. Cruickshank; D. Davy; Dal. Dalton; Dei. Deiman; H. Henry; K. Kirwan; S. Shuckburgh; T. Thomson; Th. Thenard.

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* Of temperature 190° Fahrenheit, and force = 30 inches of mercury.

† Of temperature 100° Fahrenheit, and force = 30 inches of mercury.

11.—*Rules for reducing the Volume of Gases to a mean Height of the Barometer, and mean Temperature.*

1. From the space occupied by any quantity of gas under an observed degree of pressure, to infer what its volume would be under the mean height of the barometer, taking this at 30 inches, as is now most usual.

This is done by the rule of proportion; for, as the mean height is to the observed height, so is the observed volume to the volume required. For example, if we wish to know what space would be filled, under a pressure of 30 inches of mercury, by a quantity of gas, which fills 100 inches, when the barometer is at 29 inches,

30: 29:: 100: 96.66.

The 100 inches would, therefore, be reduced to 96.66.

2. To estimate what would be the volume of a portion of gas, if brought to temperature of 60° Fahrenheit.

Divide the whole quantity of gas by 480; the quotient will show the amount of its expansion or contraction by each degree of Fahrenheit's thermometer. Multiply this by the number of degrees, which the gas exceeds, or falls below, 60°. If the temperature of the gas be above 60°, subtract, or if below 60°, add, the product to the absolute quantity of gas; and the remainder in the first case, or sum in the second, will be the answer. Thus, to find what space 100 cubic inches of gas at 50° would occupy if raised to 60°, divide 100 by 480; the quotient 0.208 multiplied by 10 gives 2.08, which added to 100 gives 102.08 the answer required. If the temperature had been 70°, and we had wished to know the volume, which the gas would have occupied at 60°, the same number 2,08 must have been subtracted from 100, and 97.92 would have been the answer.

3. In some cases, it is necessary to make a double correction, or to bring the gas to a mean both of the barometer and thermometer. We must then first correct the temperature, and afterwards the pressure. Thus to know what space 100 inches of gas at 70° Fahrenheit, and 29 inches barometer, would fill at 60° Fahrenheit and 30 inches barometer, we first reduce the 100 inches, by the second process, to 97.92. Then by the first

30: 29:: 97.92: 94.63.

Or 100 inches thus corrected, would be only 94.63.

4. To ascertain what would be the absolute weight of a given volume of gas at a mean temperature, from the known weight of an equal volume at any other temperature; first, find by the second process what would be its bulk at a mean temperature; and then say, as the corrected bulk is to the actual weight, so is the observed bulk to the number required. Thus if we have 100 cubic inches of gas weighing 50 grains at 50° Fahrenheit, if the temperature were raised to 60° they would expand to 102.08. And

102,08: 50:: 100:: 49.

Therefore 100 inches of the same gas at 60° would weigh 49 grains.

5. To learn the absolute weight of a given volume of gas under a mean pressure, from its known weight under an observed pressure, say, as the observed pressure is to the mean pressure, so is the observed weight to the corrected weight. For example, having 100 inches of gas which weigh 50 grains under a pressure of 29 inches, to know what 100 inches of the same gas would weigh, the barometer being 30 inches,

29: 30:: 50: 51·72.

Then 100 inches of the same gas, under 30 inches pressure, would weigh 51,72 grains.

6. In some cases, it is necessary to combine the two last calculations. Thus, if 100 inches of gas at 50° Fahrenheit, and under 29 inches pressure weigh 50 grains, to find what would be the weight of 100 inches at 60° Fahrenheit, and under 30 inches of the barometer, first correct the temperature, which reduces the weight to 49 grains. Then,

29: 30:: 49: 50,7.

One hundred inches, therefore, would weigh 50,7 grains.

12.—*Specific Gravities of Solid and Liquid Substances**.

	Specific Grav.		Specific Grav.
GEMS.		STONES, &c.	
Diamond, white oriental,	3,5212	Jasper, brown, . .	2,6911
Topaz, oriental, . .	4,0106	Granite, Egyptian, . .	2,6541
Sapphire, oriental, . .	3,9941	Rock-crystal, . . .	2,6530
Garnet Bohemian, .	4,1888	Chalcedony, bright, .	2,6640
Beryl, oriental, . . .	3,5489	Carrara marble, . .	2,7168
Hyacinth, common, .	3,6873	Alabaster, oriental, .	2,7302
Emerald, from Peru, .	2,7755	Carnelian, ...	2,6137
Crysolithe, from Brazil,	2,6923	Slate, common for roofs,	2,8535
Amethyst, oriental, .	2,651.	Flint, ...	2,5941
Ruby, oriental, . . .	4,2833	Agate, oriental, . .	2,5901
		Portland-stone, . . .	2,533.
STONES, &c.		Serpentine, green, Italian,	2,4295
Ponderous spar, . .	4,4300	Opal, noble, . . .	2,144.
Porphyry, ...	2,7651	Pumice-stone, . . .	0,9145

SALTS.

	Hassenfratz.	Kirwan.	Muschenbrock.	Newton.
Potash, ...	1.7085	4.6215		
Lime, ...	1.5233	2.3908	2.3700	
Magnesia, ...	0.3460	2.3298		
Alumine, ...	0.8200	2.0000		
Barytes, ...	2.3740	4.0000		
Sulphate of potash . .	2.4073	2.636	2.398	
——— alumine, .	1.7109		1.7260	1.714
——— zinc, . . .	1.9120		1.9	1.712
——— iron, . .	1.8399		1.88	
——— copper, . .	2.1943	2.23		
Nitrate of potash, . .	1.9369	1.933	1.901	1.900
Muriate of soda, . . .	2.2001		2.0835	2.143
Acetite of lead, . . .	2.3450		2.3953	
Super-tartrite of potash, .	1.9153		1.8745	
Sub-borate of soda, . .	1.7230		1.7170	1.714
Carbonate of potash, . .	2.0120		2.749	
——— soda, . .	1.3591	1.421		
——— ammonia,	0.9660	1.8245	1.5026	

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* For the specific gravities of the metals, see Table of the Qualities of Metals, near the close of this Appendix.

Table of Specific Gravities of Solid and Liquid Substances,—Continued.

	Specific Grav.
GLASSES AND VITRIFICATIONS.	
Green bottle-glass, .	2,7325
French crystal-glass,	2,8922
French mirror-glass, from St. Gobin, .	2,4882
English flint-glass, .	3,3203
China porcelain, . .	2,3847
INFLAMMABLES.	
Roll-sulphur, . . .	1,9907
Phosphorus, . . .	1,714.
Pit-Coal, ...	1,3292
Amber, ...	1,0780
Heaviest charcoal, .	0,441.
Mineral naphtha, .	0,708.
Camphor, ...	0,9887
Liquid ammonia, .	0,8970
WATERS.	
Distilled water, . .	1,0000
Sea-water, . . .	1,0263
Water from the Asphaltic Sea, . . .	1,2403
ACIDS.	
Sulphuric acid of commerce, ...	1,8500
Sulphuric acid, real, .	2,1250
Nitric acid, . . .	1,5800
Muriatic acid, . . .	1,1940
Concentrated acetic acid, ...	1,0626
SPIRITUOUS LIQUIDS.	
Maderia wine, . .	1,0382
Cyder, ...	1,0181
Brown beer, . . .	1,0338
Burgundy wine, . .	0,9915
Champaigne wine, .	0,962
Brandy, ...	0,8371
SPIRITUOUS LIQUIDS.	
Alcohol*, ...	0,8293
Nitric ether, . . .	0,9088
Acetic ether, . . .	0,8664
Sulphuric ether†, .	0,7396
Muriatic ether, . .	0,7296
ETHEREAL OILS.	
Oil of Cinnamon, .	1,0439
Oil of cloves, . . .	1,0363
Oil of lavender, . .	0,8938
Spirit of turpentine,	0,8697
FAT OILS.	
Linseed oil, . . .	0,9403
Poppy oil, ...	0,9288
Oil of sweet almonds,	0,9170
Olive oil, ...	0,9153
ANIMAL FLUIDS.	
Asses' milk, . . .	1,0355
Cows' milk, . . .	1,0324
Human milk, . . .	1,0203
Human urine, . .	1,0106
ANIMAL FATS.	
Spermaceti, . . .	0,9433
Butter, ...	0,9423
Tallow, ...	0,9419
Mutton-suet, . . .	0,9235
Train-oil, ...	0,9235
Hogs'-lard, . . .	0,9568
Ivory, ...	1,825.
Bees'-wax, . . .	0,9648
GUMS.	
Common gum, . .	1,4817
Gum-Arabic, . .	1,4523
Gum-tragacanth, . .	1,3161

* *Per* Chaussier 0.7980.

† *Per* Lovitz 0.6320.

Table of Specific Gravities of Solid and Liquid Substances,—Continued.

	Specific Grav.
GUM-RESINS.	
Asafœtida,	1,3275
Scammonium, from Smyrna,	1,2743
Galbanum,	1,2120
RESINS.	
Guaiacum,	1,2289
Jalap,	1,2185
Ammoniacum,	1,2071
Benzoe,	1,0924
Sandarac,	1,0920
White resin,	1,0819
Colophony,	1,0441
Mastich,	1,0742
Copal, transparent,	1,0452
Elastic resin,	0,9335
INSPISSATED JUICES.	
Aloe *succotrina*,	1,3795
Opium,	1,3366
WOODS.	
Lignum guaiacum,	1,3330

	Specific Grav.
WOODS.	
Box-wood, Dutch,	1,3280
French box-wood	0,9120
Ebony,	1,2090
Heart of old oak,	1,1700
Mahogany,	1,063
Olive-tree,	0,9270
Mulberry-tree, Spanish,	0,8970
Beech-tree,	0,8520
Yew-tree, Spanish,	0,8070
Apple-tree,	0,7930
Plum-tree,	0,7850
Maple-tree,	0,7550
Cherry-tree,	0,7150
Quince-tree,	0,7050
Orange-tree,	0,7050
Walnut-tree,	0,6710
Pear-tree,	0,6610
Cypress, Spanish,	0,6440
Pine-tree,	0,5500
White Spanish poplar-tree,	0,5294
Cork,	0,2400

13.—*Rules for Calculating the Absolute from the Specific Gravities of Bodies.*

In 1696, Mr. Everard, balance-maker to the Exchequer, weighed before the Commissioners of the House of Commons 2145.6 cubical inches, by the Exchequer standard foot, of distilled water, at the temperature of 55° of Fahrenheit, and found it to weigh 1131 oz. 14 dts. troy, of the exchequer standard. The beam turned with 6 grs. when loaded with 30 pounds in each scale. Hence, supposing the pound avoirdupois to weigh 7000 grs. troy, a cubic foot of water weighs $62\frac{1}{2}$ pounds avoirdupois or 1000 ounces avoirdupois, wanting 106 grains troy. And hence, if the specific gravity of water be called 1000, the proportional specific gravities of all other bodies will nearly express the number of avoirdupois ounces in a cubic foot. Or, more accurately, supposing the specific gravity of water expressed by 1, and of all other bodies in proportional numbers, as the cubic foot of water weighs, at the above temperature, exactly 437489.4 grains troy, and the cubic inch of water 253.175 grains, the absolute weight of a cubical foot or inch of any body in troy grains may be found by multiplying their specific gravity by either of the above numbers respectively.

By Everard's experiment, and the proportions of the English and French foot, as established by the Royal Society and French Academy of Sciences, the following numbers are ascertained:

Paris grains in a Paris cube foot of water . . = 645511
English grains in a Paris cube foot of water . = 529922
Paris grains in an English cube foot of water . = 533247
English grains in an English cube foot of water . = 437489.4
English grains in an English cube inch of water . = 253.175
By an experiment of Picard with the measure and weight of the Chatelet, the Paris cube foot of water contains of Paris grains . . . . = 641326
By one of Du Hamel, made with great care, . = 641376
By Homberg . . . . = 641666

These show some uncertainty in measure or in weights; but the above computation from Everard's experiment may be relied on, because the comparison of the foot of England with that of France was made by the joint labour of the Royal Society of London and the French Academy of Sciences: it agrees likewise very nearly with the weight assigned by M. Lovoisier, 70 Paris pounds to the cubical foot of water.

14.—*Table for Reducing the Degrees of Baume's Hydrometer to the Common Standard.*

Baume's Hydrometer for Liquids lighter than Water.

Temperature 55° Fahrenheit, or 10° Reaumur.

Deg.	Sp. Gr.	Deg.	Sp. Gr.	Deg.	Sp. Gr.	Deg.	Sp. Gr.
10	1.000	18	.942	26	.892	34	.847
11	.990	19	.935	27	.886	35	.842
12	.985	20	.928	28	.880	36	.837
13	.977	21	.922	29	.874	37	.832
14	.970	22	.915	30	.867	38	.827
15	.963	23	.909	31	.871	39	.822
16	.955	24	.903	32	.856	40	.817
17	.949	25	.897	33	.852		

Baume's Hydrometer for Liquids heavier than Water.

Temperature 55° Fahrenheit, or 10° Reaumur.

Deg.	Sp. Gr.	Deg.	Sp. Gr.	Deg.	Sp. Gr.	Deg.	Sp. Gr.
0	1.000	21	1.170	42	1.414	63	1.779
3	1.020	24	1.200	45	1.455	66	1.848
6	1.040	27	1.230	48	1.500	69	1.920
9	1.064	30	1.261	51	1.547	72	2.000
12	1.089	33	1.295	54	1.594		
15	1.114	36	1.333	57	1.659		
18	1.140	39	1.373	60	1.717		

N°. II.

ADMEASUREMENT AND EFFECTS OF HEAT.

1.—*Correspondence between different Thermometers.*

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

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

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

Wedgewood's pyrometer is only intended to measure very high temperatures. Its zero corresponds with 1077° of Fahrenheit's, and each degree of Wedgewood is equal to 130 of Fahrenheit.

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

Therefore $180^\circ\ F = 100^\circ\ C = 80^\circ\ R = 150^\circ\ D = \frac{18}{13}W$.

1. To reduce centigrade degrees to those of Fahrenheit, multiply by 9 and divide by 5, and to the quotient add 32, that is, $\frac{C \times 9}{5} + 32 = F$.

2. To reduce Fahrenheit's degrees to centigrade, $\frac{F - 32 \times 5}{9} = C$.

3. To reduce Reaumur's to Fahrenheit's, we have the following formula, $\frac{R \times 9}{4} + 32 = F$.

4. To convert Fahrenheit to Reaumur, $\frac{F - 32 \times 4}{9} = R$.

5. To reduce De Lisle's degrees under the boiling point, we have $F = 212 - \frac{D \times 6}{5}$. To reduce those above the boiling point, $F = 212 + \frac{D \times 6}{5}$.

6. And, inversely, to reduce Fahrenheit's degrees to De Lisle's, under the boiling point $\frac{1060 - 5F}{6} = D$; above the boiling point $\frac{F \times 5 - 1060}{6} = D$.

7. To reduce Wedgewood's degrees to those of Fahrenheit, we have $W \times 130 + 1077 = F$.

8. Inversely, to reduce Fahrenheit to Wedgewood, $\frac{F - 1077}{130} = W$.

2.—*Table of the Effects of Heats.*

1. Freezing Points of Liquids.

Fahrenheit.	
— 55	Strongest Nitric acid freezes (Cavendish)
46	Ether and liquid ammonia
39	Mercury
36	Sulphuric acid (Thomson)
22	Acetous acid
11	2 Alcohol, 1 water
7	Brandy
+ 1	Strongest sulphuric acid (Cavendish)
16	Oil of turpentine (Macquer)
20	Strong wines
23	Fluoric acid
	Oils bergamot and cinnamon
25	Human blood
28	Vinegar
30	Milk
32	Oxy-muriatic acid
	Water
36	Olive oil
46	Sulphuric acid, specific gravity 1.78 (Keir)
64	Oil of anniseeds, 50 (Thomson)

2 Melting Points of Solids.

40	Equal parts sulphur and phosphorus
82	Adipocire of muscle
97	Lard (Nicholson)
99	Phosphorus (Pelletier)
104	Resin of bile
109	Myrtle wax (Cadet)
112	Spermaceti (Bostock)
127	Tallow (Nicholson) 92 (Thomson)
149	Bees’ wax
145	Ambergris (La Grange)
155	Bleached wax (Nicholson)
212	Bismuth 5 parts, tin 3, lead 2
234	Sulphur (Hope) 212 (Fourc.) 185 (Kirw.)
235	Adipocire of biliary calculi (Fourcroy)
283	Tin and bismuth, equal parts

Fahren.	Wedge.	
303		Camphor
334		Tin 3, lead 2, or tin 2, bismuth 1
442		Tin (Chrichton) 413 (Irvine)
460		Tin 1, lead 4
476		Bismuth (Irvine)
612		Lead (Chrichton) 594 (Irvine) 540 (Newton)
700		Zinc
809		Antimony
3809	21	Brass
4587	27	Copper
4717	28	Silver
5237	32	Gold
17977	130	Cobalt
20577	150	Nickel
21097	154	Soft nails
21637	158	Iron
21877	160	Manganese
23177	+ 170	Platina, Tungsten, Molybdena, Uranium, Titanium, &c.

3. Solids and Liquids Volatilized.

98		Ether boils
140		Liquid ammonia boils
145		Camphor sublimes (Venturi)
170		Sulphur evaporates (Kirwan)
176		Alcohol boils, 174 (Black)
212		Water and essential oils boil
219		Phosphorus distils (Pelletier)
230		Muriate of lime boils (Dalton)
242		Nitrous acid boils
248		Nitric acid boils
283		White arsenic sublimes
540		Metallic arsenic sublimes
554		Phosphorus boils
560		Oil of turpentine boils
570		Sulphur boils
590		Sulphuric acid boils (Dalton) 546 (Black)
600		Linseed oil boils, Sulphur sublimes (Davy)
660		Mercury boils (Dalton) 644 (Secondat) 600 (Black) 672 (Irvine)

4. Miscellaneous Effects of Heat.

Fahren.	Wedg.	
—90		Greatest cold produced by Mr. Walker
50		Natural cold observed at Hudson's bay
23		Observed on the surface of the snow at Glasgow, 1780
14		At Glasgow, 1780
0		Equal parts, snow and salt
+ 43		Phosphorus burns slowly
59		Vinous fermentation begins
66		to 135, Animal putrefaction
75		to 80, summer heat in this climate
77		Vinous fermentation rapid, acetous begins
80		Phosphorus burns in oxygen, 104 (Gottling)
88		Acetification ceases
96		to 100, Animal temperature
107		Feverish heat
122		Phosphorus burns vividly (Fourcroy) 148 (Thomson)
130		Ammonia disengaged from water
165		Albumen coagulates, 156 (Black)
303		Sulphur burns slowly
635		Lowest heat of ignition of iron in the dark
800		Hydrogen burns, 1000 (Thomson)
802		Charcoal burns (Thomson)
1050		Iron red in twilight
1077		Iron red in daylight
1300		Azotic gas burns
1077	1	Iron red in daylight
1300	+ 2	Azotic gas burns
1807	6	Enamel colours burned
2897	14	Diamond burns (M'Kenzie) 30 W = 5000 F (Morveau)
6507	40	Delft ware fired
8480	57	Working heat of plate glass
10177	70	Flint glass furnace
12257	86	Cream-coloured ware fired
13297	94	Worcester china vitrified
14337	102	Stone Ware fired
14727	105	Chelsea china fired
15637	112	Derby china fired
15897	114	Flint glass furnace greatest heat
16007	121	Bow china vitrified
16807	124	Plate glass greatest heat
17327	125	Smith's forge
20577	150	Hessian crucible fused
25127	185	Greatest heat observed

3. *Table of the Force of Steam at different Temperatures, from actual experiment. (Betancourt in Prony's Architecture Hydraulique.)*

Temperature.	Force in Inches of Mercury.	Temperature.	Force in Inches of Mercury.
32°	0	162°	9.07
42	.08	172	11.0
52	.21	182	14.9
62	.38	192	18.7
72	.58	202	23.7
82	.87	212	29.8
92	1.26	222	37.4
102	1.74	232	46.5
112	2.37	242	57.3
122	3.16	252	69.7
132	4.16	262	83.6
142	5.43	272	97.1
152	7.00	282	108.

In the 5th volume of "Memoirs of the Manchester Society," a table of the force of vapour, for each degree of Fahrenheit, is given by Mr. Dalton; the numbers below 212 degrees from experiment, and the higher numbers from calculation. Mr. Betancourt, however, professes to have obtained all the above results from actual experiment.

4. *Table of the Expansion of a given bulk of Air, between* 32° 212° *Fahrenheit.*

Temp.	Bulk.	Temp.	Bulk.	Temp.	Bulk.
32°	100000	59°	105616	86°	111232
33	100208	60	105824	87	111440
34	100416	61	106032	88	111648
35	100624	62	106240	89	111856
36	100832	63	106448	90	112064
37	101040	64	106656	91	112272
38	101248	65	106864	92	112486
39	101456	66	107070	93	112688
40	101664	67	107280	94	112896
41	101872	68	107488	95	113104
42	102080	69	107696	96	113312
43	102288	70	107904	97	113520
44	102496	71	108112	98	113728
45	102764	72	108320	99	113936
46	102912	73	108528	100	114144
47	103120	74	108736	110	116224
48	103328	75	108944	120	118304
49	103536	76	109152	130	120384
50	103744	77	109360	140	122464
51	103952	78	109568	150	124544
52	104160	79	109776	160	126624
53	104268	80	109984	170	128704
54	104576	81	110192	180	130784
55	104784	82	110400	190	132864
56	104992	83	110608	200	134944
57	105220	84	110816	210	137024
58	105408	85	111024	212	137440

5. *Table of the Expansion of Liquids by Heat.*

Temp.	Mercury.	Linseed Oil.	Sulphuric Acid.	Nitric Acid.	Water.	Oil of Turpentine.	Alcohol.
32°	100000	100000	—	—	—	—	100000
40	100081	—	99752	99514	—	—	100539
50	100183	—	100000	100000	100023	100000	101105
60	100304	—	100279	100486	100091	100460	101688
70	100406	—	100558	100990	100197	100993	102281
80	100508	—	100806	101530	100332	101471	102890
90	100610	—	101054	102088	100694	101931	103517
100	100712	102760	101317	102620	100908	102446	104162
110	100813	—	101540	103196	—	102943	—
120	100915	—	101834	103776	101404	103421	—
130	101017	—	102097	104352	—	103954	—
140	101119	—	102320	105132	—	104573	—
150	101220	—	102614	—	102017	—	—
160	101322	—	102893	—	—	—	—
170	101424	—	103116	—	—	—	—
180	101526	—	103339	—	—	—	—
190	101628	—	103587	—	103617	—	—
200	101730	—	103911	—	—	—	—
212	101835	107250	—	—	104577	—	—

6. *Table of the Expansion of Water by Heat.*

Temp.	Expansion.	Temp.	Expansion.
42.5°	100000	112.5°	100777
52.5	100030	122.5	101006
62.5	100106	132.5	101220
72.5	100182	142.5	101495
82.5	100273	152.5	101755
92.5	100471	162.5	102040
102.5	100624	172.5	102260

7. *Table of the Expansion of Solids by Heat.*

Temp.	Platina†.	Antimon.	Steel.	Iron	Cast Iron.	Bismuth.
32°	120000	120000	120000	120000	120000	120000
212	120104	120130	120147	120151		120167
White heat*			123428	121500	122571	

	Copper.	Cast Brass.	Brass Wire.	Tin.	Lead.	Zinc.
32°	120000	120000	120000	120000	120000	120000
212	120204	120225	120232	120298	120344	120355

	Hammered zinc.	Zinc 8 Tin 1	Lead 2 Tin 1	Brass 2 Zinc 1	Pewter.	Copper 3 Tin‡ 1
32°	120000	120000	120000	120000	120000	120000
212	120373	120323	120301	120247	120274	120218

Expansion of Glass.

Temp.	Bulk.	Temp.	Bulk.	Temp.	Bulk.
32°	100000	100°	100023	167°	100056
50	100006	120	100033	190	100069
70	100014	150	100044	212	100083

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* Rinman. † Borda.

‡ The metal, whose expansion is here given, was an alloy composed of three parts of copper, and one of tin. The figures in some of the preceding columns are to be understood in the same manner. Thus, in the last column but two, the metal consisted of two parts of brass, alloyed with one of zinc.

8.—*Table of Freezing Mixtures.*

Mixtures.	Thermometer sinks.
Muriate of ammonia 5 parts Nitre . . . 5 Water . . 16	From 50° to 10°
Muriate of ammonia 5 Nitre . . . 5 Sulphate of soda . 8 Water . . 16	From 50 to 4
Nitrate of ammonia 1 Water . . 1	From 50 to 4
Nitrate of ammonia 1 Carbonate of soda 1 Water . . 1	From 50 to 7
Sulphate of soda . 3 Diluted nitric acid 2	From 50 to 3
Sulphate of soda . 6 Muriate of ammonia 4 Nitre . . 2 Diluted nitric acid 4	From 50 to 10
Sulphate of soda . 6 Nitrate of ammonia 5 Diluted nitric acid 4	From 50 to 14
Phosphate of soda 9 Diluted nitric acid 4	From 50 to 12
Phosphate of soda 9 Nitrate of ammonia 6 Diluted nitric acid 4	From 50 to 21
Sulphate of soda . 8 Muriatic acid . . 5	From 50 to 0

Table of Freezing Mixtures—Continued.

Mixtures.	Thermometer sinks.
Sulphate of soda . 5 parts Diluted sulphuric acid . . 4	From 50° to 3°
Snow . . . 1 Common salt . 2	From 32 to 0
Muriate of lime . 3 Snow . . 2	From 30 to —50
Potash (crystallized) 4 Snow . . 3	From 32 to —51
Snow . . 1 Diluted sulphuric acid . . 1	From 20 to —60
Snow, or pounded ice 2 Common salt . 1	From 0 to —5
Snow and diluted nitric acid	From 0 to —46
Muriate of lime . 2 Snow . . 1	From 0 to —66
Snow, or pounded ice 1 Common salt . 5 Muriate of ammonia and nitre . . 5	From —5 to —18
Snow . . . 2 Diluted sulphuric acid . . . 1 Diluted nitric acid 1	From —10 to —56
Snow, or pounded ice . . 12 Common salt . 5 Nitrate of ammonia 5	From —18 to —25
Muriate of lime . 3 Snow . . 1	From —40 to —73
Diluted sulphuric acid . . . 10 Snow . . 8	From —68 to —91

9.—*Table of the Specific Heats or Capacities of Bodies, altered from* Dr. Thomson's *System of Chemistry, 3d Edition.*

N. B. The bodies compared are taken in equal weights, and the specific heat of water is assumed to be 1.

I. Gases.

Hydrogen	21.4000*
Oxygen	4.7490*
Common air	1.7900*
Carbonic acid	1.0459*
Azote	0.7036*

II. Water.

Ice	0.9000†
Water	1.0000
Steam	1.5500*

III. Saline Solutions.

Carbonate of ammonia		1.851*
Sulphuret of do.	(0.818)	0.994*
Sulphate of magnesia Water	1 2	0.844*
Muriate of soda Water	1 8	0.832*
Nitrate of potash Water	1 8	0.8167‡
Ditto		0.914(I.)
Nitrate of potash Water	1 3	0.646†
Muriate of ammonia Water	1 1.5	0.798†
Super-tartrite of potash Water	1 273.3	0.765†
Sulphate of iron Water	1 2.5	0.734†
Sulphate of soda Water	1 2.9	0.728†
Alum Water	1 2.9	0.649†
Nitric acid Lime	$9\frac{1}{3}$ 1	0.6189‡
Solution of brown sugar		1.086†

IV. Acids and Alkalies.

Nitric Acid	pale	0.844†
	(1.2989)	0.6613‡ 0.62(L.) 0.68(D.)
	(1.355)	0.570†
Muriatic acid	(1.122)	0.680†
Sulphuric acid	(1.885)	0.758†
	(1.872)	0.429†
	(do.)	0.34(L.)
	(1.87)	0.3345‡
		0.339 (G.)
		0.350 (D.)
Do. 4, Water 5		0.6631‡
Do. 4, do. 3.		0.6031‡
Vinegar Do. distilled		0.92(D.)
Acetic acid (spec. gr. 1.056)		0.668(D.)
Potash	(1.346)	0.759†
Ammonia	(0.997)	0.708†
Ammonia	(0.948)	1.030(D.)

V. Inflammable Liquids.

Alcohol	(850)	0.760(D.)
		0.6666*
		0.64(L.)
		0.6024*
		1.086†
Oil of olives		0.716†
		0.500(L.)
Linseed oil		0.528†
Spermaceti		0.5000*
Oil of turpentine		0.472†
Spermaceti		0.399†

VI. Animal Fluids.

Arterial blood	1.0300*
Venous blood	0.8928*
Cow's milk	0.9999*

VII. Animal Solids.

Ox-hide, with hair	0.7870*
Lungs of a sheep	0.7690*
Lean of ox-beef	0.7400*

VIII. Vegetable Solids.

Pinus sylvestris	0.65¶
Pinus abies	0.60¶
Tilea Europæa	0.62¶
Pinus picea	0.58¶
Pyrus malus	0.57¶
Betula alnus	0.53¶
Quercus robur sessilis	0.51¶

Fraxinus excelsior	0.51¶
Pyrus communis	0.50¶
Rice	0.5050*
Horse beans	0.5020*
Dust of the pine-tree	0.5000*
Peas	0·4920*
Fagus sylvatica	0.49¶
Carpinus betulus	0 48¶
Betula alba	0.48¶
Wheat	0.4770¶
Elm	0.47¶
Quercus robur pedunculata	0.45¶
Prunus domestica	0.44¶
Diaspyrus ebenum	0.43¶
Barley	0.4210*
Pit coal	0.2777*
Charcoal	0.2631*
Oats	0.4160*
Cinders	0.1923*

IX. EARTHY BODIES, STONE-WARE, AND GLASS.

Chalk	0.2564*
Quick-lime	0.2229* 0.2168‡
Ashes of pit coal	0.1855*
——— elm	0.1402*
Agate	0.195§
Stone-ware	0.195†
Crystal	0.1929‡
Swedish glass	0.187§
Flint glass	0.174†

X. SULPHUR . . 0.183

XI. METALS.

Iron	0.125† 0.1269* 0.126§
Brass	0.1123* 0.116§
Copper	0.1111* 0.114§
Sheet iron	0.1099‡
Gun metal	0.1100‖
Zinc	0.0943* 0.102§
Silver	0.082§
Tin	0.068† 0.0704‡ 0.060§
Antimony	0.086† 0.0645* 0.063§
Gold	0.050§
Lead	0.050† 0.0352* 0.042§
Bismuth	0.043§
Mercury	0.033† 0.0357* 0.0290‡ 0.040(D.)

XII. METALLIC OXIDES.

Oxide of iron	0.320†
Rust of iron	0.2500*
Do. nearly freed from air	0.1666*
White oxide of antimony washed	0.220† 0.2272*
Do. nearly freed from air	0.1666
Oxide of copper do.	0.2272*
Oxide of lead and tin	0.102†
Oxide of zinc	0.1369*
Oxide of tin, nearly freed from air	0.0990* 0.096†
Yellow oxide of lead	0.0680* 0.068†

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* Crawford,—† Kirwan,—‡ Lavoisier and La Place,—§ Wilcke,—¶ Meyer,—(L.) Leslie,—‖ Count Rumford,—(D.) Dalton,—(I.) Irvine jun.

N°. III.

1.—Table *of the Solubility of Salts in Water.*

NAMES OF SALTS.	Solubility in 100 Parts Water	
	At 60°.	At 212°.
ACIDS.		
Arsenic,	150.	
Benzoic,	0.208	4.17
Boracic,	....	2.
Camphoric,	1.04	8.3
Citric,	133.	200.
Gallic,	8.3	66.
Mucic,	0.84	1.25
Molybdenic,	....	0.1
Oxalic,	50.	100.
Suberic,	0.69	50.
Succinic,	4.	50.
Tartarous,	Very soluble.	
SALIFIABLE BASES.		
Barytes,	5.	50.
crystallized,	57.	Unlimited.
Lime,	0·2	
Potash,	Very soluble.	
Soda,	Very soluble.	
Strontites,	0.6	
crystallized,	1.9	50.
SALTS.		
Acetate of ammonia,	Very soluble.	
barytes,	do.	
lime,	do.	
magnesia,	do.	
potash,	100.	
soda,	Very soluble.	
strontites,	....	40.
Carbonate of ammonia,	+30.	100.
barytes,	Insoluble.	
lime,	Insoluble.	
magnesia,	2.	
potash,	25.	83.
soda,	50.	+100.
strontites,	Insoluble.	

TABLE *of the Solubility of Salts in Water—Continued.*

NAMES OF SALTS.	Solubility in 100 Parts Water	
SALTS.	At 60°.	At 212°.
Camphorate of ammonia,	1.	33.
barytes,	0.16	
lime,	0.5	
potash,	33.	+33.
Citrate of soda,	60.	
lime,	Insoluble.	
Hyper-oxymuriate of barytes,	25.	+25.
mercury,	25.	
potash,	6.	40.
soda,	35.	+35.
Muriate of ammonia,	33.	100.
barytes,	20.	+20.
lead,	4.5	
lime,	200.	
magnesia,	100.	
mercury,	5.	50.
potash,	33.	
silver,	0.$\frac{1}{30}$	
soda,	35.42	36.16
strontites,	150.	Unlimited.
Nitrate of ammonia,	50.	200.
barytes,	8.	25.
lime,	400.	
magnesia,	100.	+100.
potash,	14.25	100.
soda,	33.	+100.
strontites,	100.	200.
Oxalate of strontites,	0.$\frac{1}{19}$	
Phosphate of ammonia,	25.	+25.
barytes,	0.	0.
lime,	0.	0.
magnesia,	6.6	
potash,	Very soluble.	
soda,	25.	50.
strontites,	0.	0.
Phosphite of ammonia,	50.	+50.
barytes,	0.$\frac{1}{4}$	
potash,	33.	+33.
Sulphate of ammonia,	50.	100.
barytes,	0.002	

TABLE *of the Solubility of Salts in Water—Continued.*

NAMES OF SALTS.	Solubility in 100 Parts Water	
	At 60°.	At 212°.
SALTS.		
Sulphate of copper,	25.	50.
iron,	50.	+100.
lead,	0.$\frac{1}{12}$	
lime,	0.2	0.22
magnesia,	100.	133.
potash,	6.25	20.
soda,	37.	125.
strontites,	0.	0.02
Sulphite of ammonia,	100.	
lime,	0.125	
magnesia,	5.	
potash,	100.	
soda,	25.	100.
Saccholactate of potash,		12.
soda,		20.
Sub-borate of soda (borax),	8.4	16.8
Super-sulphate of alumine and potash (alum),	5.	133.
potash,	50.	+100.
Super-oxalate of potash,		10.
tartrite of potash,	1.$\frac{2}{3}$	3.$\frac{1}{3}$
Tartrite of potash,	25.	
and soda,	20.	
antimony and potash,	6.6	33.

2.—*Table of Substances Soluble in Alcohol.*

NAMES OF SUBSTANCES.	Temperature.	100 parts Alcohol dissolve
Acetate of copper,	176°	7 5
soda,	176°	46.
Arsenate of potash,	do.	3.75
soda,	do.	1.7
Boracic acid,	do.	20.
Camphor,	do.	75.
Muriate of ammonia,	do.	7·
alumine,	54½°	100.
copper,	176°	100.
iron,	176°	100.
lime,	do.	100.
magnesia,	do.	547.
mercury,		88.3
zinc,	54½°	100.
Nitrate of ammonia,	176°	89.2
alumine,	54½°	100.
cobalt,	54½	100.
lime,		125.
potash,	176°	2.9
silver,	do.	41.7
Succinic acid,	do.	74.
Sugar, refined,	do.	24½
Super-oxalate of potash,		3.
Tartrite of potash,		0.04

OTHER SUBSTANCES SOLUBLE IN ALCOHOL. All the acids, except the sulphuric, nitric, and oxy-muriatic, which decompose it, and the phosphoric and metallic acids.—Potash, soda, and ammonia, very soluble. Soaps; extract; tan; volatile oils; adipocire; resins; urea.

SUBSTANCES INSOLUBLE, OR VERY SPARINGLY SOLUBLE, IN ALCOHOL. Earths; phosphoric and metallic acids; almost all sulphates and carbonates; the nitrates of lead and mercury; the muriates of lead, silver, and soda (the last, *per* Chenevix, sparingly soluble); the sub-borate of soda; the tartrite of soda and potash, and super-tartrite of potash; fixed oils; wax; starch; gum; caoutchouc; woody fibre; gelatine; albumen, and gluten.

3.—Kirwan's Table, *showing the Composition of Salts.*

COMPONENT PARTS.

SALTS.	BASIS.	ACID	WATER.	STATE.
Carbonate of potash	41.	43.	16.	Crystallized.
Pearl-ash	60.	30.	6.	Dry.
Carbonate of soda	21.58	14.42	64.	Fully crystallized.
ditto	59.86	40.05		Desiccated.
barytes	78.	22.		Natural or ignited.
strontian	69.5	30.		Natural or ignited.
lime	55.	45.		Natural if pure, or artificial ignited.
magnesia	25.	50.	25.	Crystallized.
common ditto	45.	34.	21.	Dried at 80°.
Sulphate of potash	54.8	45.2		Dry
soda	18.48	23.52	58.	Fully crystallized.
ditto	44.	56.		Desiccated at 700°.
ammonia	14.24	54.66	31.1	
barytes	66.66	33.33		Natural and pure, artificial ignited.
strontian	58.	42.		Natural and pure, artificial ignited.
lime	32.	46.	22.	Dried at 66°.
ditto	35.23	50.39	14.38	Dried at 170°.
ditto	38.81	55.84	5.35	Ignited.
ditto	41.	59.		Incandescent.
magnesia	17.	29.35	53.65	Fully crystallized.
ditto	36.68	63.32		Desiccated.
Alum	12. ignited.	17.66	51. of crystals + 19.24 in the earth.	Crystallized.
Ditto	63.75	36.25		Desiccated at 700°.

TABLE, *showing the Composition of Salts—Continued.*

COMPONENT PARTS.

SALTS.	BASIS.	ACID.	WATER.	STATE.
Nitrate of potash	51.8	44.	4.2 of Composition	Dried at 70°.
soda	40.58	53.21	6.21 of Composition	Dried at 400°.
ditto	42.34	57.55	. . . . . .	Ignited.
ammonia	23.	57.	20.	
barytes	57.	32.	11.	Crystallized.
strontian	36.21	31.07	32.72	Crystallized.
lime	32.	57.44	10.56	Well dried, that is, in air.
magnesia	22.	46.	22.	Crystallized.
Muriate of potash	64.	36.	. . . . . .	Dried at 80°.
soda	53.	47. aqueous, 38.88 real	. . . . . .	Dried at 80°.
ammonia		. . . . . .	. . . . . .	Crystallized.
ditto	25.	42.75	32.25	Sublimed.
barytes	64.	20.	16.	Crystallized.
ditto	76.2	23.8.	. . . . . .	Desiccated.
strontian	40.	18.	42.	Crystallized.
ditto	69.	31.	. . . . . .	Desiccated.
lime	50.	42.	8.	Red hot.
magnesia	31.07	34.59	34.34	Sensibly dry.

4.—*Table of Incompatible Salts**.

SALTS.	INCOMPATIBLE WITH
1. Fixed alkaline sulphates	Nitrates of lime and magnesia, Muriates of lime and magnesia.
2. Sulphate of lime . .	Alkalies, Carbonate of magnesia, Muriate of barytes.
3. Alum	Alkalies, Muriate of barytes, Nitrate, muriate, carbonate of lime, Carbonate of magnesia.
4. Sulphate of magnesia .	Alkalies, Muriate of barytes, Nitrate and muriate of lime.
5. Sulphate of iron . .	Alkalies, Muriate of barytes, Earthy carbonates.
6. Muriate of barytes .	Sulphates, Alkaline carbonates, Earthy carbonates.
7. Muriate of lime . .	Sulphates, except of lime, Alkaline carbonates, Carbonate of magnesia.
8. Muriate of magnesia .	Alkaline carbonates, Alkaline sulphates.
9. Nitrate of lime . .	Alkaline carbonates, Carbonates of magnesia and alumine, Sulphates, except of lime.

5.—*Quantity of Real Acid taken up by mere Alkalies and Earths, (Kirwan.)*

100 Parts.	Sulphuric	Nitric.	Muriatic.	Carbonic Acid.
Potash.	82,48	84,96	56,3	105, almost.
Soda.	127,68	135,71	73,41	66,8.
Ammonia.	383,8	247,82	171,	Variable.
Baryt.	50,	56,	31,8	282.
Strontia.	72,41	85,56	46,	43,2
Lime.	143,	179,5	84,488	81,81.
Magnesia.	172,64	210,	111,35	200, Fourcroy.
Alumine.	150,9			335, nearly, Bergman.

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* That is, salts which cannot exist together in solution, without mutual decomposition.

6.—*Quantity of Alkalies and Earths taken up by* 100 *parts of real Sulphuric, Nitric, Muriatic, and Carbonic Acids, Saturated, (Kirwan.)*

100 Parts.	Potash.	Soda.	Ammo-nia	Baryt.	Strontia.	Lime.	Mag.
Sulphuric.	121,48	78,32	26,05	200,	138,	70,	57,92
Nitrous.	117,7	73,3	40,35	178,12	116,86	55,7	47,64
Muriatic.	177,6	136,2	58,48	314,46	216,21	118,3	898,
Carbonic.	95,1	149,6		354,5	231,+	122,	50,

7.—TABLE, *by* RICHTER, *of the Quantity of each Base required for the Saturation of the different Acids.* (From BERTHOLLET's *Statique Chimique*, 1re Partie, p. 136.).

The experiments, from which the following Table was deduced, we are assured by Berthollet, were the principal occupation of Richter from the year 1791 to 1800; and, from the attention with which they were performed, appear to be deserving of considerable confidence. An example will best explain the method of using the Table. Take the article *potash* in the first column, opposite to which is placed the number 1605. The numbers in the other column show how much of each acid is required to saturate 1605 parts of potash, viz. 427 parts of fluoric acid, 575 of carbonic acid, &c. In a similar manner, take any acid in the second column, the oxalic for instance: The first column shows how much of each base effects the saturation of 755 parts of oxalic acid, viz. 525 of alumine, 615 of magnesia, &c.

BASES.	
Alumine	525
Magnesia	615
Ammonia	672
Lime	793
Soda	859
Strontites	1329
Potash	1605
Barytes	2222

ACIDS.	
Fluoric	427
Carbonic	577
Sebacic	706
Muriatic	712
Oxalic	755
Phosphoric	979
Formic	988
Sulphuric	1000
Succinic	1209
Nitric	1405
Acetic	1480
Citric	1563
Tartarous	1694

8.—TABLE, *showing the specific Gravity af Mixtures of Alcohol and Water**.

Centesimal parts of the Mixture.		SPECIFIC GRAVITIES.	
		According to Chaussier.	According to Gilpin, (last Table.)
Alcohol -	100	0.7980	0.825
	95	0.8165	0.83887
	90	0.8340	0.85244
	85	0.8485	0.86414
	80	0.8620	0.87606
	75	0.87525	0.88762
	70	0.8880	0.89883
	65	0.9005	0.90941
	60	0.9120	0.91981
	55	0.9230	0.92961
	50	0.9334	0.93882
	45	0.94265	0.94726
	40	0.9514	0.95493
	35	0.95865	0.96158
	30	0.96535	0.96736
	25	0.97035	0.97239
	20	0.97605	0.97723
	15	0.9815	0.98213
	10	0.9866	0.98737
	5	0.99335	0.99327
	0	0.99835	1.00000

9.—TABLE, *showing the Component Parts of Nitric Acid of different Colours and Densities, by Mr.* DAVY.

100 Parts.	Specific Gravity.	COMPONENT PARTS.		
		Nitric Acid	Water.	Nitrous Gas.
Solid nitric acid .	1.504	91.55	8.45	—
Yellow nitrous . .	1.502	90.5	8.3	2.
Bright yellow .	1.500	88.94	8.10	2.96
Dark orange . .	1.480	86.84	7.6	5.56
Light olive . .	1.479	86.00	7.55	6.45
Dark olive . . .	1.478	85.4	7.5	7.1
Bright green . .	1.476	84.8	7.44	7.76
Blue green . . .	1.475	84.6	7.4	8.00

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* Chaussier's alcohol had the specific gravity of 0.798; and Gilpin's that of 0.825. The tables of Gilpin are to be found in the Philosophical Transactions for 1794.

N°. IV.

1.—TABLE, *showing some of the Qualities of Metals; the Proportion of Oxygen with which they Combine; and the Colours of their Oxides, (Compiled from two of the Tables in Thomson's Chemistry.)*

Metals.	Colour.	Specific Grav.	Fusing Point	No. of Oxides.	Colours of Oxides.	Propor. of Oxygen.
Gold	Yellow	19.361	32 W.	1 2	Purple Yellow	 10.
Platina	White	23.000	+170W.	1 2	Green Brown	.7½ 0.15
Palladium	White	11.871	+160W.	1 2	Blue Yellow ?	
Rhodium	White	+11	+160W.	1 2	 Yellow	
Iridium	White		+160W.	1 2	Blue ? Red ?	
Osmium	Blue			1	Transparent	
Silver	White	10.510	22 W.	1 2	 Olive	 12.8
Mercury	White	13.568	—39 F.	1 2 3	Black Red	5. 11.
Copper	Red	8.895	27 W.	1 2	Red Black	13. 25.
Iron	Blue-grey	7.788	158 W.	1 2	Black Red	37. 92.3
Tin	White	7.299	442 F.	1 2	Grey White	25. 38.8

TABLE, *showing some of the Qualities of Metals, &c.—Continued.*

Metals.	Colour.	Specific Grav.	Fusing Point.	No. of Oxides.	Colours of Oxides.	Propor. of Oxygen.
Lead	Blueish-white	11.352	612 F.	1		
				2	Yellow	10.6
				3	Red	13.6
				4	Brown	25.
Nickel	White	8.666	+ 160 W.	1	Green	28.
				2	Black	
Zinc	White	6.861	680 F.	1	Yellow	13.6
				2	White	25.
Bismuth	White	9.822	476 F.	1		
				2	Yellow	12.
Antimony	Grey	6.712	809 F.	1	White	22.7
				2	Ditto	30.
Arsenic	White	8.310	+ 400 F.?	1	White	33.
				2	White (acid)	53.
Cobalt	White	7.700	130 W.	1	Blue	
				2	Green	
				3	Black	
Manganese	White	6.850	+ 160 W.	1	White	25.
				2	Red	35.
				3	Black	66.6
Molybdena	Grey	8.600	+ 170 W.	1	Light brown	
				2	Violet	
				3	Blue	34.
				4	White	50.
Tellurium	White	6.115	+ 612 F.	1	White	
				2		
Tungsten	Greyish-white	17.6	+ 170 W.	1	Black	
				2	Yellow	25.
Uranium	Grey	9.000	+ 170 W.	1	Black	5.17
				2	Yellow	28.

TABLE, *showing some of the Qualities of Metals, &c.—Continued.*

Metals.	Colour.	Specific Grav.	Fusing Point.	No. of Oxides.	Colours of Oxides.	Propor. of Oxygen.
Titanium	Red		+170 W.	1 2 3	Blue Red White	
Chromium	White		+170 W.	1 2 3	Green Brown Red	200
Columbium					White	
Tantalium					White	
Cerium	White			1 2	White Red	

N. B.—The numbers, in the last column of the foregoing Table, denote the quantity of oxygen with which 100 parts of each metal combine. Thus, to form the black oxide of iron, 100 parts of the metal absorb 37 oxygen, and afford 137 of an oxide, which, in 100 parts, contain 27 of oxygen.—In the column showing the fusing point, W. added to the numerals, denote the degrees of Wedgewood's pyrometer, and F. those of Fahrenheit's thermometer.

2.—*Colour of the Precipitates thrown down from Metallic Solutions, by various Re-agents.*

Metals.	Prussiated Alkalies.	Tincture of Galls.	Water impregnated with Sulphuretted Hydrogen.	Hydro-Sulphurets.
Gold	Yellowish-white	Solution turned green. Precipitate brown of reduced gold.	Yellow.	Yellow.
Platina	No precip.; but an orange coloured one by pruss. of mercur.	Dark-green becoming paler.	Precipitated in a metallic state.	
Silver	White	Yellowish-brown.	Black.	Black.
Mercury	White, changing to yellow.	Orange yellow.	Black.	Brownish-black.
Palladium	Olive*. Deep orange†.		Dark-brown.	Dark-brown.
Rhodium	No precip.			No precip.
Iridium	No precipitate. Colour discharged.	No percipitate. Colour of solutions discharged.		
Osmium		Purple, changing to deep vivid blue.		

---

* Chenevix. † Wollaston.

Colour of Precipitates from Metallic Solutions, &c.—Continued.

Metals.	Prussiated Alkalies.	Tincture of Galls.	Water impregnated with Sulphuretted Hydrogen.	Hydro-Sulphurets.
Copper	Bright reddish-brown.	Brownish	Black.	Black.
Iron { 1. Green salts	White, changing to blue.	No precipitate.	Not precipitated.	Black.
2. Red salts	Deep blue.	Black.		
Nickel	Green.	Greyish-white.	Not precipitated.	Black.
Tin	White.	No precip.	Brown.	Black.
Lead	White.	White.	Black.	Black.
Zinc	White.	No precip.	Yellow.	White.
Bismuth	White.	Orange.	Black.	Black.
Antimony	White.	A white oxide merely from dilution.	Orange.	Orange.
Tellurium	No precip.	Yellow.		Blackish.
Arsenic	White.	Little change.	Yellow.	Yellow.
Cobalt	Brownish-yellow.	Yellowish-white.	Not precipitated.	Black.
Manganese	Yellowish-white.	No precip.	Not precipitated.	White.
Chrome	Green.	Brown.		Green.
Molybdena	Brown.	Deep-brown.	Brown.	

Colour of Precipitates from Metallic Solutions, &c.—Continued.

Metals.	Prussiated Alkalies.	Tincture of Galls.	Water impregnated with Sulphretted Hydrogen.	Hydro-Sulphurets.
Uranium	Brownish-red.	Chocolate.		Brownish-yellow.
Tungsten				
Titanium	Grass-green, with a tinge of brown.	Reddish-brown.	Not precipitated.	Grass-green.
Columbium	Olive.	Orange.		Chocolate.
Tantalium				
Cerium		Yellowish.		Brown, becoming deep green.

3.—TABLE, *showing the Maximum Quantity of Oxygen taken up by different Substances.*

SIMPLE COMBUSTIBLES.

100 Hydrogen unite with	597.7 Oxygen
100 Carbon	257.
100 Azote	236.
100 Muriatic acid	194.
100 Phosphorus	154.
100 Sulphur	71.3

METALS.

100 Chrome combine with	200. Oxygen
100 Iron	92.3
100 Manganese	66.
100 Arsenic	53.
100 Tin	38.8
100 Antimony	30.
100 Zinc	25.
100 Copper	
100 Lead	
100 Tungsten	
100 Murcury	17.6
100 Platina	15.
100 Silver	12.8
100 Bismuth	12.
100 Gold	10.

No. V.

TABLE OF SIMPLE AFFINITY*.

OXYGEN.

- Carbon,
- Charcoal,
- Manganese,
- Zinc,
- Iron,
- Tin,
- Antimony,
- Hydrogen,
- Phosphorus,
- Sulphur,
- Arsenic,
- Nitrogen,
- Nickel,
- Cobalt,
- Copper,
- Bismuth,
- Caloric ?
- Mercury,
- Silver,
- Arsenous acid
- Nitric oxide,
- Gold,
- Platina,
- Carbonic oxide,
- Muriatic acid,
- White oxide of manganese,
- White oxide of lead.

OXYGEN†.

- Titanium,
- Manganese,
- Zinc,
- Iron,
- Tin,
- Uranium,
- Molybdena,
- Tungsten,
- Cobalt,
- Antimony,
- Nickel,
- Arsenic,
- Chrome,
- Bismuth,
- Lead,
- Copper,
- Tellurium,
- Platina,
- Mercury,
- Silver,
- Gold.

CARBON.

- Oxygen,
- Iron,
- Hydrogen.

NITROGEN.

- Oxygen,
- Sulphur ?
- Phosphorus,
- Hydrogen.

HYDROGEN.

- Oxygen,
- Sulphur,
- Carbon,
- Phosphorus,
- Nitrogen.

SULPHUR. PHOSPHORUS?

- Potash,
- Soda,
- Iron,
- Copper,
- Tin,
- Lead,
- Silver,
- Bismuth,
- Antimony
- Mercury,
- Arsenic,
- Molybdena.

POTASH, SODA, AND AMMONIA.

- *Acids.* Sulphuric,
  - Nitric,
  - Muriatic,
  - Phosphoric,
  - Fluoric,
  - Oxalic,
  - Tartaric,
  - Arsenic,
  - Succinic,
  - Citric,
  - Lactic,
  - Benzoic,
  - Sulphurous,
  - Acetic,
  - Mucic,
  - Boracic,
  - Nitrous,
  - Carbonic,
  - Prussic,
- Oil,
- Water,
- Sulphur.

BARYTES.

- *Acids.* Sulphuric,
  - Oxalic,
  - Succinic,
  - Fluoric,
  - Phosphoric,
  - Mucic,
  - Nitric,
  - Muriatic,
  - Suberic,
  - Citric,
  - Tartaric,
  - Arsenic,
  - Lactic,
  - Benzoic,
  - Acetic,
  - Boracic,
  - Sulphurous,
  - Nitrous,
  - Carbonic,
  - Prussic,
- Sulphur,
- Phosphorus,
- Water,
- Fixed Oils.

STRONTITES.

- *Acids.* Sulphuric,
  - Phosphoric,
  - Oxalic,
  - Tartaric,
  - Fluoric,
  - Nitric,
  - Muriatic,
  - Succinic,
  - Acetic,
  - Arsenic,
  - Boracic,
  - Carbonic,
- Water.

LIME.

- *Acids.* Oxalic,
  - Sulphuric,

---

* This table, it may be necessary to observe, does not express accurately the *comparative affinities* of bodies, but denotes merely the actual *order of decomposition*, which, as Berthollet has shewn, may often be contrary to that of affinity, owing to the influence of various extraneous forces.

† Vauquelin's Table of the affinity of the metals for oxygen, according to the difficulty with which their oxides are decomposed by heat.

Table of Simple Affinity—Continued.

Tartaric,
Succinic,
Phosphoric,
Mucic,
Nitric,
Muriatic,
Suberic,
Fluoric,
Arsenic,
Lactic,
Citric,
Malic,
Benzoic,
Acetic,
Boracic,
Sulphurous,
Nitrous,
Carbonic,
Prussic,
Sulphur,
Phosphorus,
Water,
Fixed oil.

MAGNESIA.

Acids. Oxalic,
Phosphoric,
Sulphuric,
Fluoric,
Arsenic,
Mucic,
Succinic,
Nitric,
Muriatic,
Tartaric,
Citric,
Malic ?
Lactic,
Benzoic,
Acetic,
Boracic,
Sulphurous,
Nitrous,
Carbonic,

Prussic,
Sulphur.

ALUMINE.

Acids. Sulphuric,
Nitric,
Muriatic,
Oxalic,
Arsenic,
Fluoric,
Tartaric,
Succinic,
Mucic,
Citric,
Phosphoric,
Lactic,
Benzoic,
Acetic,
Boracic,
Sulphurous,
Nitrous,
Carbonic,
Prussic.

SILEX.

Fluoric acid,
Potash.

OXIDE OF PLATINA.
——— GOLD*.

Gallic acid,
Muriatic,
Nitric,
Sulphuric,
Arsenic,
Fluoric,
Tartaric,
Phosphoric,
Oxalic,
Citric,

Acetic,
Succinic,
Prussic,
Carbonic,
Ammonia.

OXIDE OF SILVER.

Gallic acid,
Muriatic,
Oxalic,
Sulphuric,
Mucic,
Phosphoric,
Sulphurous,
Nitric,
Arsenic,
Fluoric,
Tartaric,
Citric,
Lactic,
Succinic,
Acetic,
Prussic,
Carbonic,
Ammonia.

OXIDE OF MERCURY.

Gallic acid,
Muriatic,
Oxalic,
Succinic,
Arsenic,
Phosphoric,
Sulphuric,
Mucic,
Tartaric,
Citric,
Malic,
Sulphurous,
Nitric,
Fluoric,
Acetic,

Benzoic,
Boracic,
Prussic,
Carbonic.

OXIDE OF LEAD.

Galic,
Sulphuric,
Mucic,
Oxalic,
Arsenic,
Tartaric,
Phosphoric,
Muriatic,
Sulphurous,
Suberic,
Nitric,
Fluoric,
Citric,
Malic,
Succinic,
Lactic,
Acetic,
Benzoic,
Boracic,
Prussic,
Carbonic,
Fixed oils,
Ammonia.

OXIDE OF COPPER.

Gallic,
Oxalic,
Tartaric,
Muriatic,
Sulphuric,
Mucic,
Nitric,
Arsenic,
Phosphoric,
Succinic,
Fluoric,

---

* Omitting the oxalic, citric, succinic, and carbonic, and adding sulphuretted hydrogen after ammonia.

Table of Simple Affinity—Continued.

Citric,
Lactic,
Acetic,
Boracic,
Prussic,
Carbonic,
Fixed alkalies,
Ammonia,
Fixed oils.

OXIDE OF ARSENIC.

Gallic,
Muriatic,
Oxalic,
Sulphuric,
Nitric,
Tartaric,
Phosphoric,
Fluoric,
Succinic,
Citric,
Acetic,
Prussic,
Fixed Alkalies,
Ammonia,
Fixed oils,
Water.

OXIDE OF IRON.

Gallic,
Oxalic,
Tartaric,
Camphoric,
Sulphuric,
Mucic,
Muriatic,
Nitric,
Phosphoric,
Arsenic,
Fluoric,

Succinic,
Citric,
Lactic,
Acetic,
Boracic,
Prussic,
Carbonic.

OXIDE OF TIN*.

Gallic,
Muriatic,
Sulphuric,
Oxalic,
Tartaric,
Arsenic,
Phosphoric,
Nitric,
Succinic,
Fluoric,
Mucic,
Citric,
Lactic,
Acetic,
Boracic,
Prussic,
Ammonia.

OXIDE OF ZINC.

Gallic,
Oxalic,
Sulphuric,
Muriatic,
Mucic,
Nitric,
Tartaric,
Phosphoric,
Citric,
Succinic,
Fluoric,
Arsenic,
Lactic,

Acetic,
Boracic,
Prussic,
Carbonic,
Fixed alkalies,
Ammonia.

OX. OF ANTIMONY.

Gallic,
Muriatic,
Benzoic,
Oxalic,
Sulphuric,
Nitric,
Tartaric,
Mucic,
Phosphoric,
Citric,
Succinic,
Fluoric,
Arsenic,
Lactic,
Acetic,
Boracic,
Prussic,
Fixed alkalies,
Ammonia.

SULPHURIC ACID.
PRUSSIC†.

Barytes,
Strontites,
Potash,
Soda,
Lime,
Magnesia,
Ammonia,
Glucine,
Yttria,
Alumine,

Zircon,
Metallic oxides.

SULPHUROUS ACID.
SUCCINIC‡.

Barytes,
Lime,
Potash,
Soda,
Strontites,
Magnesia,
Ammonia,
Glucine,
Alumine,
Zircon,
Metallic oxides.

PHOSPHORIC ACID.
CARBONIC§.

Barytes,
Stronites,
Lime,
Potash,
Soda,
Ammonia,
Magnesia,
Glucine,
Alumine,
Zircon,
Metallic oxides,
Silex.

PHOSPHOROUS ACID.

Lime,
Barytes,
Strontites,
Potash,

---

* Burgman places the tartaric before the muriatic.

† With the omission of all after ammonia.

‡ Ammonia should come before magnesia; and strontites, glucine, and zircon, should be omitted.

§ Magnesia should stand above ammonia, and alumine and silica should be omitted.

Table of Simple Affinity—Continued.

Soda,
Ammonia,
Glucine,
Alumine,
Zircon,
Metallic oxides.

NITRIC ACID.
MURIATIC—[*].

Barytes,
Potash,
Soda,
Strontites,
Lime,
Magnesia,
Ammonia,
Glucine,
Alumine,
Zircon,
Metallic oxides.

FLUORIC ACID.
BORACIC—[†].
ARSENIC—[‡].
TUNGSTIC—

Lime,
Barytes,
Strontites,
Magnesia,

Potash,
Soda,
Ammonia,
Glucine,
Alumine,
Zircon,
Silex.

ACETIC ACID.
LACTIC —
SUBERIC—[§].

Barytes,
Potash,
Soda,
Strontites,
Lime,
Ammonia,
Magnesia,
Metallic oxides,
Glucine,
Alumine,
Zircon.

OXALIC ACID.
TARTARIC—
CITRIC —[||].

Lime,
Barytes,
Strontites,

Magnesia,
Potash,
Soda,
Ammonia,
Alumine,
Metallic oxides,
Water,
Alcohol.

BENZOIC ACID.

White oxide of Arsenic,
Potash,
Soda,
Ammonia,
Barytes,
Lime,
Magnesia,
Alumine.

CAMPHORIC ACID.

Lime,
Potash,
Soda,
Barytes,
Ammonia,
Alumine,
Magnesia.

FIXED OIL.

Lime,
Barytes,
Potash,
Soda,
Magnesia,
Oxide of Mercury,
Other metallic oxides,
Alumine.

ALCOHOL.

Water,
Ether,
Volatile Oil,
Alkaline Sulphurets.

SULPHURETTED HYDROGEN.

Barytes.
Potash,
Soda,
Lime,
Ammonia,
Magnesia,
Zircon.

---

[*] Ammonia should stand above magnesia.

[†] Silex should be omitted, and, instead of it, water and alcohol be inserted.

[‡] Except silex.

[§] With the omission of strontites, metallic oxides, glucine, and zircon.

[||] Zircon after alumine.

APPENDIX. II.

DESCRIPTION OF THE PLATES.

PLATE. I.

FIG. 1 (*a*). *A plain retort*, the neck of which is shown introduced a proper length into the mouth of a plain receiver *b*. The dotted lines at *c* show the receiver with the addition of a tubulure, into which either a stopper, or bent glass tube, may be occasionally fixed.

FIG. 2. *A glass alembic; a* the body, and *b* the head, which are ground so as to fit accurately, and may be separated when necessary. The head *b* is so shaped, that any liquid, which may be condensed, collects into a channel, and is carried by the pipe *c* into a receiver.

FIG. 3. *A separator*, for separating liquids of different specific gravities. It is furnished with a ground stopper at *a*, and a glass stop-cock at *b*. The vessel is filled with the liquids that are to be separated (oil and water for example), which are allowed to stand till the lighter has completely risen to the top. The stopper *a* is then removed, and the cock *b* opened, through which the heavier liquid descends; the cock being shut, as soon as the lighter one is about to flow out.

FIG. 4. A glass vessel, termed a *matrass*, useful for effecting the solution of bodies, which require heat before they can be dissolved, or long continued digestion, see chap. i. sect. ii. The upper extremity of the long neck generally remains cool, and allows the vessel and its contents to be shaken occasionally.

FIG. 5. A glass bottle with a very thin bottom, and a projecting ring round the neck for suspending it over a lamp. These are useful for effecting *solutions* on a small scale.

FIG. 6. An apparatus, contrived by Mr. Pepys, *for ascertaining the quantity of carbonic acid discharged from any substance by the addition of an acid.* It consists of a bottle, closed by a ground stopper. This stopper is perforated, and forms the lower part of a tube, which is twisted into the shape of a still-worm. In this worm, any water that escapes along with the gas, is condensed, and falls down again into the bottle. The experiment is made precisely as described, chap. x. sect. iv. art. 6.: and the loss of weight is determined at the close of the effervescence.

Fig. 7. Mr. Leslie's *differential thermometer* described, chap iii. sect. i.

Fig. 8. *a*, *an air thermometer*, for ascertaining the temperature of liquids. It consists of a bottle, partly filled with any coloured liquid, and partly with air, a glass tube of small bore, open at both ends, being either cemented or hermetically sealed into the bottle, so that its lower extremity may nearly touch the bottom of the bottle. The expansion of the included air, on the application of heat, drives the coloured liquid up the tube, and to an extent which may be measured by the application of a scale. The fig. *b* is another variety of the same instrument, described chap. iii. sect. i.

Fig. 9. The original *air Thermometer of Sanctorio* ; see chap. iii. sect. i.

Fig. 10. A bent funnel for introducing liquids into retorts, without soiling their necks.

Fig. 11. *An adopter*. The wider end admits the neck of a retort ; and the narrower is passed into the mouth of a receiver.

Fig. 12. A section of an evaporating dish of Wedgewood's ware.

Fig. 13. (*a*) *a tubulated retort* luted to (*b*) *a quilled receiver*, the pipe of which enters the neck of a bottle (*c*) supported by a block of wood.

Fig. 14. *A bottle for ascertaining the specific gravity of liquids.* When filled up to a mark in the neck, with distilled water of a given temperature, it should hold 1000, 2000, or any even number of grains. The quantity, which it is found to contain, of any other liquid of the same temperature, shows the specific gravity of the latter. For example, if it hold 1000 grains of water, and 1850 of sulphuric acid, the specific gravity of the latter is to that of water as 1850 to 1000.

Fig. 15. A tube, blown in the middle into a ball, for dropping liquids. The ball is filled by the action of the mouth applied to the upper orifice, while the lower one is immersed in the liquid. To the former the finger is then applied ; and, on cautiously removing it, the liquid is expelled in drops.

Fig. 16. A glass jar, with a lip, for decanting fluids from precipitates.

PLATE II.

Fig. 17. An apparatus for procuring gases, without the possibility of their escaping into the room during the process, a circumstance which is of considerable importance when the gas has an unpleasant smell or deleterious properties. Suppose that sulphuretted hydrogen gas is to be obtained from sulphuret of iron and diluted sulphuric acid. The sulphuret of iron, in coarse powder, is put into the body of the gas bottle *c*, with a proper quantity of water. The acid holder *a* is filled with the diluted acid, the cock *b* being shut, and is then fixed into the tubulure of the gas bottle, to which it is accurately adapted by grinding.

The bent tube *d* being made to terminate under a receiver filled with, and inverted in water, the perforated cock *b* is gradually opened, in consequence of which the acid descends into the gas bottle ; and acts on the sulphuret of iron. If it be found necessary to renew the acid, without disturbing the apparatus, this may be done as follows. The cock *b* being shut, the stopper, which closes the acid holder, may be removed, and fresh acid be poured in, through the aperture. This may be repeated as often as is found necessary. The acid holder may be advantageously adapted, also, to a retort for certain distillations, such as that of muriatic acid.

FIG. 18. A plain gas bottle with sigmoid tube, the end, which is received into the bottle, having a ground stopper accurately fitted to the neck. For ordinary purposes (such as obtaining hydrogen gas from diluted sulphuric acid and iron filings) this apparatus answers perfectly well, and is much less costly. It is frequently made with a tubulure and glass stopper, and is then called a tubulated gas bottle.

FIG. 19. A gas funnel, useful in transferring any gas, from a wide-mouthed vessel into a jar of narrower diameter, or into a bottle.' When employed for this purpose, it is held inverted, as shown by the figure, the pipe being admitted into the aperture of the bottle or jar, which is filled with and inverted in water, and the gas being made to pass into it in bubbles.

FIG. 20. Dr. Hope's Eudiometer. The manner of using it has already been described, chap. v. sect. iv.

FIG. 21. A jar for receiving gases. FIG. 23. The same with a ground stopper.

FIG. 22. A gas receiver, into the neck of which is cemented a brass cap, with a female screw for receiving a stop-cock. The vessel *b* is a glass flask, which may be made to communicate with the interior of the jar *a*, by opening the cock. When the apparatus is used, it is necessary to employ two stop-cocks, and not one only, as represented by the figure. Supposing that the weight of any gas is to be ascertained, the flask *b* is exhausted, by screwing it on the transfer of an air pump ; and, if great accuracy be required, it is proper to enclose a gage in the vessel. Let the flask be weighed when exhausted ; then screw it upon the top of the receiver, containing the gas which is to be weighed ; and open the communication, observing, by using a graduated jar, how much gas has been admitted. Suppose this to be 50 cubic inches. By weighing the flask again when full, we determine the weight of 50 cubic inches of the gas under examination. The experiment should be made when the temperature of the room is 60°, and when the barometer stands at 29.8.

FIG. 24. An Eudiometer for trying the purity of a mixture of gases containing oxygen gas, by means of nitrous gas. The process has already been described, chap. xii. sect. ii. The instrument should be accompanied with a vial, holding, when completely full, precisely a cubic inch.

FIG. 25. A wire stand, with a leaden foot, for the purpose of raising, above the surface of water within a jar, any substance which is to be exposed to the action of gas.

FIG. 26. An apparatus for showing that caloric exists in gases in a latent form. The application of it has been already described, chap. v.

FIG. 27. A glass jar, partly filled with air, and partly with quicksilver, and standing inverted in quicksilver. The use of this figure is merely to illustrate the method of inferring the real from the apparent quantity of gas in a tube, when the quicksilver within is above the level of the fluid without, as explained, chap. v. sect. i.

FIGS. 28 and 29. Tubes for exploding mixtures of hydrogen and other inflammable gases with oxygen gas, commonly termed the Eudiometer of Volta; see chap. v. sect. v.

PLATE III.

FIG. 30. The common form of a Woulfe's apparatus. In this figure the retort *a* is represented plain, but it is better to employ a tubulated one. The use of this apparatus has already been described, chap. i. sect. ii.

FIG. 31. A modification of the apparatus, which has also been already described. In this figure, the mercurial trough is shown with a jar standing inverted in it, for the purpose of receiving any gas that may escape condensation by water.

FIG. 32. Mr. Pepys' improvement of Woulfe's apparatus described, chap. i. sect. ii.

PLATE IV.

FIGS. 33 and 34. Cuthbertson's apparatus, for exhibiting the composition of water, with the substitution of gazometers for the receivers originally employed by him. The apparatus has been described, chap. vi. sect. i. Fig. 33. is an enlarged view of the conical brass piece, which is cemented into the bottom of the receiver, and through which the gases are conveyed.

FIG. 35. A gazometer of the most simple and common construction; see chap. v. sect. i.

FIG. 36. A gas-holder, described in the same section.

FIG. 37. A galvanic trough (see chap. vi. sect. ii.). The tube *b* shows the arrangement for decomposing water. The upper wire may be hermetically sealed into the tube, and the lower one passed through a cork, which should have a small slit cut in it, to allow the water to escape in drops as the gas is produced.

FIG. 38. The manner in which a candle may be burned in oxygen gas; see chap. v. sect. ii.

FIG. 39. The combustion of iron-wire in oxygen gas.

FIG. 40. Apparatus for decomposing water over red-hot iron or charcoal; see chap. vi. sect. ii.

FIG. 41. A contrivance for showing the diminution of hydrogen and oxygen gases by slow combustion; see chap. v. sect. v.

Fig. 42. A very simple and cheap contrivance for freezing quicksilver by muriate of lime and snow. The outer vessel of wood may be twelve and a half inches square, and seven inches deep. It should have a wooden cover, rabbeted in, and furnished with a handle. Within this is placed a tin vessel *b b*, standing on feet which are one and a half inch high, and having a projection at the top, half an inch broad, and an inch deep, on which rests a shallow tin-pan *c c*. Within the second vessel is a third *d*, made of untinned iron, and supported by feet two inches high. This vessel is four inches square, and is intended to contain the mercury. When the apparatus is used, a mixture of muriate of lime and snow is put into the outer vessel *a a*, so as completely to surround the middle vessel *b b*. Into the latter, the vessel *d*, containing the quicksilver to be frozen, previously cooled down by a freezing mixture, is put; and this is immediately surrounded by a mixture of snow and muriate of lime, previously cooled to 0° Fahrenheit, by an artificial mixture of snow and common salt. The pan *c c* is also filled with these materials, and the wooden cover is then put into its place. The vessels are now left, till the quicksilver is frozen. A more elegant, but more expensive, apparatus, by Mr. Pepys, intended for the same purpose, is figured in an early volume of the Philosophical Magazine.

Fig. 43. A wire stand, consisting of an interior circle, and three straight pieces of wire proceeding from it in the same plane. Its use is noticed, chap. v. sect. ii.

Fig. 44. Mr. Davy's apparatus for the analysis of soils, described in his paper, which is copied into the third part of this work.

PLATE V.

. Fig. 45. Pictet's arrangement of an apparatus for showing the radiation of caloric, unaccompanied by light; see chap. iii. sect. i.

Fig. 46. An oval copper boiler, for exhibiting the most important facts respecting latent caloric. The size of its different parts (except the width, which is 4 inches) may be learned from the scale affixed to the plate, which is abundantly sufficient to enable any intelligent workman to construct the apparatus. The collar-joint and stuffing box, however, it is indispensably necessary to describe, especially as the former article of apparatus is generally constructed on a bad plan.

Fig. 47. is a section, upon a larger scale, of the collar-joint at *b* (fig. 46.), made for the convenience of screwing together long or crooked metal tubes, without turning them round. *a* is a section of the end of one of the tubes, and *b* that of the other which is to be attached to it; *c* is a collar which turns loose upon the shoulder of *a*, and screws upon *b*. By screwing this collar upon *b*, the end *e* of the tube *a* is brought to press upon the part *d* of the tube *b*, without turning round either of those tubes. If upon *d* be laid a ring of linen cloth soaked in boiled linseed-oil, the joint, when

screwed up (if tolerably well made), will be impervious to steam, as well as to water or air. The projection at *d* is for preserving the ring of cloth from being displaced, and for guiding the ends of both tubes, so as to meet properly.

Fig. 48. is a section of a socket, for fixing the stem of a thermometer into a boiler or a digester, where there is much heat and pressure; *b* is a socket fixed on the outside of the boiler or digester, having a hole through it large enough to admit the bulk of the thermometer; *a* is a plug which screws into *b*, having a hole through its centre large enough to admit only the stem of the thermometer; *c c* is a loose round plate, concave on the upper side, having a hole through its centre, just sufficient also to admit the stem of the thermometer. When the instrument is to be inserted, the plug *a*, and the plate *c*, must both be taken out of the socket. The bulb is then passed through it. The plate *c* is next slipped over the stem, and dropped into its place. Some flax, soaked in linseed-oil, must next be wrapped round the stem, so as nearly to fill the socket. The plug *a* must then be screwed in, till the flax be compressed so as to make the whole sufficiently tight. The opposite surfaces of the plate *c*, and the plug *a*, are made concave, for the purpose of compressing the flax round the stem of the thermometer.

PLATE VI.

Fig. 49, 50, 51. Sections of crucibles.

Fig. 52. A muffle; see chap. i. sect. ii.

Fig. 53. Stands for raising the crucible above the bars of the grate; *a* one adapted to Mr. Aikin's blast furnace; *b* one of the common form.

Fig. 54. A skittle-shaped crucible.

Fig. 55. Mr. Aikin's portable blast furnace. It is composed of three parts, all made out of the common thin black-lead melting pots, sold in London for the use of the goldsmiths. The lower piece *c* is the bottom of one of these pots, cut off so low as only to leave a cavity of about an inch, and ground smooth above and below. The outside diameter over the top is five and a half inches. The middle piece, or fire-place *a*, is a larger portion of a similar pot, with a cavity about six inches deep, and measuring seven and a half inches over the top, outside diameter, and perforated with six blast holes at the bottom. These two pots are all that are essentially necessary to the furnace for most operations; but when it is wished to heap up fuel above the top of a crucible contained within, and especially to protect the eyes from the intolerable glare of the fire when in full heat, an upper pot *b* is added, of the same dimensions as the middle one, and with a large opening in the side, cut to allow the exit of the smoke and flame. It has also an iron stem, with a wooden handle (an old chisel answers the purpose very well) for removing it occasionally.

The bellows, which are double (*d*), are firmly fixed, by a little contrivance which will take off and on, to a heavy stool, as represented in the plate; and their handle should be lengthened so as to make them work easier to the hand. To increase their force on particular occasions, a plate of lead may be firmly tied on the wood of the upper flap. The nozzle is received into a hole in the pot *c*, which conducts the blast into its cavity. From hence the air passes into the fire-place *a*, through six holes of the size of a large gimlet, drilled at equal distances through the bottom of the pot; and all converging in an inward direction, so that, if prolonged, they would meet about the centre of the upper part of the fire. Fig. 56. shows the distribution of these holes in the bottom. The large central hole is intended to receive the stand *a*, fig. 53, which serves for supporting the crucible.

No luting is necessary in using this furnace, so that it may be set up and taken down immediately. Coak, or common cinders, taken from the fire when the coal just ceases to blaze, sifted from the dust, and broken into very small pieces, forms the best fuel for higher heats. The fire may be kindled at first by a few lighted cinders, and a small quantity of wood-charcoal.

The heat which this little furnace will afford is so intense, that its power was, at first, discovered accidentally by the fusion of a thick piece of cast iron. The utmost heat procured by it was 167° of Wedgewood's pyrometer piece, which was withdrawn from a Hessian crucible, when actually sinking down in a state of porcellaneous fusion. A steady heat of 155° or 160° may be depended on if the fire be properly managed, and the bellows worked with vigour. (See Philosophical Magazine, vol. xvii. p. 166.)

By a letter from Mr. Aikin, I have learned, also, a convenient, way of exhibiting, in a lecture, and performing at other times, the process of cupellation, by means of this furnace. It consists in causing a portion of the blast to be diverted from the fuel, and to pass through a crucible in which the cupel is placed. This arrangement supplies air; and the whole may be seen by a sloping tube, run through the cover of the crucible. Fig. 57. shows the furnace when used for this purpose; *a a* the furnace; *b* the perforated stopper for the central blast; *c c* a portion of earthen tube, through which the air passes, and is heated during this transit; *e* a piece of soft brick, perforated to admit the earthen tube *f*, which may be kept open for inspecting the process. No luting is required, except to join *f* to *e*.

Fig. 58. Knight's portable furnace, composed of strong iron plate, lined with fire-lute, the inside diameter six inches. *a* shows the grate; *b* the ash-pit door; *d* the door of the fire placed when used as a sand heat; *e e* two holes opposite to each other for transmitting a tube; *g* an opening for a retort neck, when used for distilling with the naked fire.

Fig. 59. A different view of the same furnace; *a* the grate; *c* the register to the ash-pit; *f* a small door, with a contrivance for

supporting a muffle. The other letters correspond with the explanation of the preceding figure.

For this furnace the proper fuel, when it is used as a wind-furnace, is wood-charcoal, either alone, or with the admixture of a small proportion of coak. For distillation with a sand heat, charcoal, with a little pit-coal, may be employed.

PLATE VII.

Fig. 60. represents a fixed furnace, which I find very useful, because it may either be employed as a wind-furnace, or for distillation with a sand heat. Its total height outside is thirty-three inches, and the outside square is eighteen inches, or two bricks laid lengthwise. The thickness of the sides of the furnace is the breadth of a brick, or four and a half inches ; but whenever there is room, it is better to make them nine inches in thickness. From the top of the furnace to the grate, which is moveable, and supported by two bearers, the height is thirteen inches ; and at *c* is a double Rumford door ; or, in preference, a hole, closed by a moveable earthern-stopper, for introducing fuel. The ash-pit should have a register door. The chimney is four inches wide by three high, and may either be furnished with a damper or not. On the top of the furnace a cast-iron ring is fixed, ten inches inside diameter, three inches broad, and half an inch thick. It is secured in its place by three iron-pins, passing through three equidistant holes in the ring, and bent at the distance of nine inches at a right angle. These serve the purpose of binding the ring firmly into the brick-work. The sand pots are of different sizes ; and a variety of them may be made to fit the same ring, by varying the breadth of their rims, as shown, fig. 71. The bricks should be cemented together, at least for the inner half of their breadth, by loam, or by a mixture of Stourbridge clay, with two or three parts sand, and a proper quantity of water.

When this is used as a wind-furnace, the opening in the side is to be closed by its stopper; or, if a Rumford door be employed, it must be defended from the fuel by a fire-tile. The fuel (coak) is introduced at the top, which is occasionally covered by a fire-tile. When distillation with a sand heat is performed, the sand-pot rests on the iron-ring, and the fuel, which may be common pit-coal, is added through the opening in the side. It may be proper to state, that, in order to receive a sand-pot of as large a size as possible, the upper course of brick should be bevilled within the furnace; and the width at the top may exceed a little that at the grate.

The best Stourbridge or Newcastle-on-Tyne fire-bricks are necessary in constructing this and the following furnaces.

Fig. 61. is a longitudinal section of a wind-furnace, invented by Mr. Knight, with an additional chamber for applying the waste heat to useful purposes. *a* the internal cavity, which is square, for containing the fuel and the crucible. *b* the flue passing into

a hot chamber *c*; an appendage particularly useful for drying luted crucibles, or bringing them to a proper temperature for the furnace; for roasting ores, and various other purposes. *d* the flue connecting it with the vertical chimney *e*; which, to produce a strong heat, should never be less than thirty or forty feet high. *ff* covers, consisting of twelve inch Welsh tiles, with handles. *g* the stoke hole, through which no more of the fire is seen than appears between the grate and the bearing bar *h*. This space is left for the double purpose of raking the fire, and occasionally taking out the bars. *k* the ash-pit, which is sunk below the level of the ground, and is covered, where it projects at *l*, by an iron grating.

The best situation for this furnace, is an angle of the laboratory, the chimney being in the corner, as represented in the sketch. By this arrangement, the operator is spared the disagreeable necessity of scorching his legs, by standing opposite the stoke hole, while the backs of his legs are exposed to a current of cold air rushing to the furnace.

Figs. 62. and 63. are different views of a furnace invented by Mr. Knight, and convertible to various purposes.

The inside of this furnace is nine inches square, and sixteen inches deep from the top to the grate. The face of the opening at *g* rises at an angle, which makes the back part five inches higher than the front. This contrivance enables us completely to cover a large retort with fuel, without obstructing the passage of the air, and also relieves partly the weight of the cover, when it requires to be moved. The walls of the furnace are at least a brick and a half in thickness, and as much more as local convenience will allow. By sinking the ash-pit below the level of the ground, at *i*, the height of the furnace needs not exceed eighteen inches, which renders the management of the fuel much more easy, and subjects the face and hands less to the action of the heat. The ash-pit *a*, must be at least eighteen inches deep, below the surface of the ground, and more if convenient. It must have an opening, projecting from it three or four feet, to be covered with boards, and with an iron grating next the furnace. This preserves the legs of the operator from the action of the fire.

The grate *b* is formed of separate bars, each of a triangular shape, three-fourths of an inch apart, and resting on two bearers. In the front of the furnace, an iron bar is to be placed to support the brick-work, and to leave an opening, through which the bars may occasionally be drawn out, and the fire be raked and cleared of the slag. The chimney *e* is two and a half inches from the top, and four and a half wide, by two and a half high.

To fit this furnace for occasional distillation with the naked fire, an opening, *d*, fig. 62, is left on one side, which is filled up, when not wanted, by five pieces of soft fire-brick, cut to a proper shape, and secured by a clay lute. It is proper, also, to be provided with other pieces, having arched openings for transmitting the neck of a retort. One of these pieces may have a round hole for occasionally transmitting a tube, and a corresponding hole, *h*, fig. 63. must then be made in the opposite side of the furnace, to be closed, when not wanted, with a stopper.

Figs. 64 and 65, represent a sand heat, for containing flat evaporating vessels ; the depth from back to front two feet ; the width, agreeably to the scale, six feet. At the front is a rim four inches deep, consisting of a piece of iron plate, which is fastened at each end into the wall. The floor or bottom, *e e*, is formed of cast-iron plates, which rest upon each other in corresponding rabbets. The advantage of several small plates, over one large one, is the cheapness and facility, with which they are replaced, if cracked by the heat, an accident of not infrequent occurrence. The joints are secured by a fire lute, which effectually prevents the sand from falling through. The fire place is shown by *b* ; at the bottom it has a grate ten inches long, by eight wide. The flame and smoke circulate first through the flue *c*, and then through the returning flue *d*, which conveys the smoke to the chimney *g*. In constructing the flue beneath the grate, a row of bricks, set edgeways, answers the purpose, and serves also to support the inner edge of the plates.

It is adviseable to cover the sand heat with a sloping roof, which may be formed of lath and plaster, and supported by side walls. The lowest part of the roof may be foremost, and about three feet above the edge of the iron plates. It is, also, necessary to have an air-flue, nearly at the top of the back wall, under the dome or roof, to be closed occasionally by a door. This must open into the chimney, in which case it serves the purpose of carrying off noxious vapours.

PLATE VIII.

Figs. 66, 67, 68, are the section and plans of a reverberatory furnace for experimental purposes. In this furnace, the fuel is contained in an anterior fire-place ; and the substance, to be submitted to the action of heat, is placed on the floor of another chamber, situated between the front one and the chimney. The flame of the fuel passes into the second compartment ; by the form of which it is concentrated upon the substance exposed to heat, which is not confined in a separate vessel or crucible, but placed on the floor of the furnace. When reduced to a state of fusion, the melted mass is allowed to flow out through a tap-hole at *h*. The dimensions of this furnace it is scarcely possible to state, as they vary so considerably in different parts of it ; but they may be ascertained by referring to the figures, and by the application of the scale. In all three figures, *a* represents the ash-pit ; b the grate composed of moveable bars ; *c* the door at which the fuel is introduced ; *d* a door in the side of the chamber, for the purpose of inspecting the process; *e* the floor of the furnace which descends, and is gradually contracted towards the back part; *f* another door for introducing and stirrring the materials; *g* the back part of the furnace, immediately under the chimney; *h* the tap-hole; *i* the chimney.

Figs. 69 and 70, exhibit a cupelling or *enamelling furnace.* The form of this should be an oblong square; its dimensions being regulated by that of the muffle, which should go home to the back, its front edge lodging on the mouth of the furnace. On each side of the muffle, two inches and a half must be left, to let the fuel pass readily underneath, where there should also be a similar space. A stoke-hole must be left on the other side, but the situation of the view will not admit its being shown. Before the muffle, is a projecting ledge or shelf, shown at *e*, which is intended to support any thing that is to be put into the muffle. Two twelve-inch tiles, worked in along with the bricks, will answer this purpose. In both figures, *a* shows the ash-pit; *c* the grate; *d* the muffle; *e* the opening for introducing the muffle; *f* the chimney, and *g* the cover.

Fig. 71, sand pots with rims of different sizes.

Figs. 72, 73. Doctor Black's portable furnace, made of sheet-iron lined with fire-clay. Its dimensions, as they vary in almost every part, will best be learned from the scale; *a* the fire-place; *b* the chimney; *e* the ash-pit; *d* the door of the ash-pit; *e* a register for regulating the quantity of air admitted to pass through the fuel.

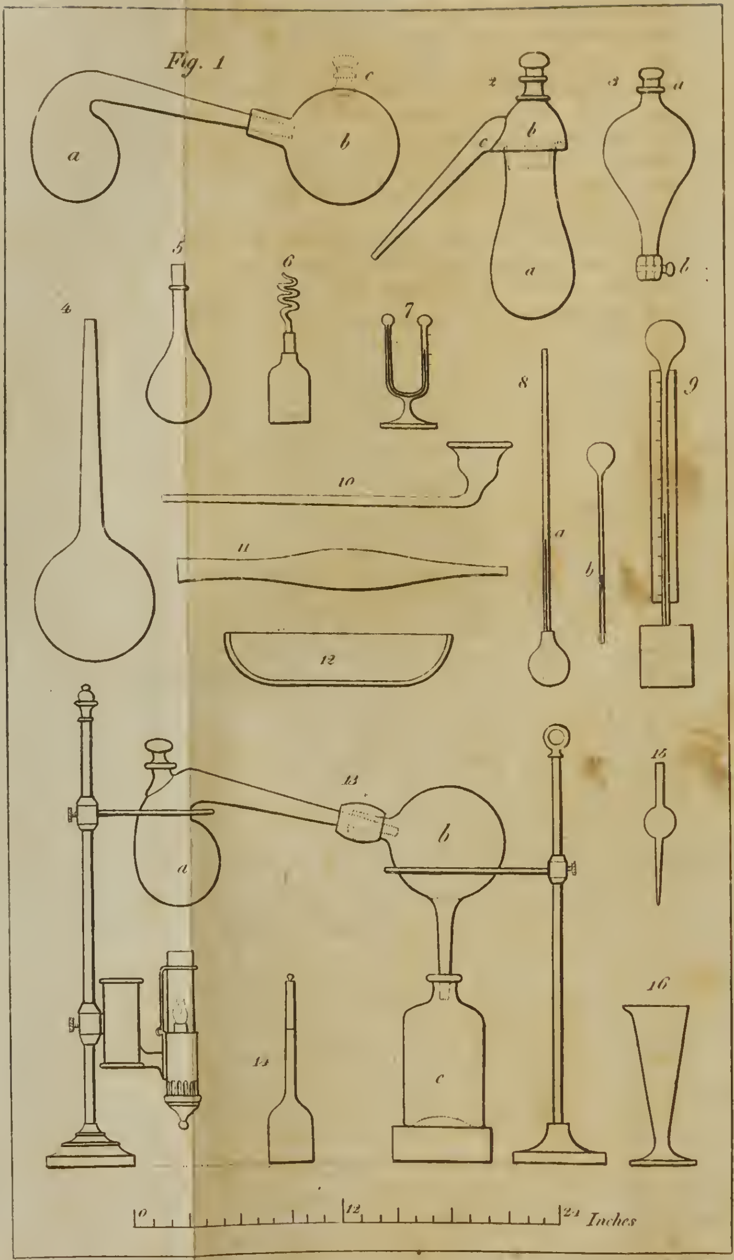
Fig. 74. Mr. Chenevix's wind furnace. This is rudely sketched in Nicholson's Journal, from which the more accurate figure in plate viii. is taken. This furnace Mr. Chenevix describes as ollows: "I have constructed a wind furnace, which, in some espects, is preferable to the usual form. The sides, instead of being perpendicular, are inverted; so that the hollow space is pyramidal. At the bottom the space is twelve inches square, and at the top only eight. The perpendicular height is seventeen inches, from the top to the grate. This form unites the following advantages. 1. A large surface is exposed to the air, which, having an easy entrance, rushes through the fuel with great rapidity. 2. The inclined sides act as reverberators. 3. The fuel falls of itself, and is always close to the grate."

In the figure, *a* represents the grate; *c c* are two bricks which can be let in at pleasure, to diminish the capacity: *b* is another grate which can be placed on the bricks *c c*, for occasional purposes; *d d* are bricks, which can be placed on the grate *b*, to diminish the capacity of this part of the furnace; *e* the cover. Both sets of bricks should be ground to the slope of the furnace.

In the construction of every furnace, which is intended to produce a strong heat, lime or mortar should be avoided, and the bricks should be set in loam, or Stourbridge clay, worked up with water and sand, inserting occasionally pieces of sheet-iron, bent twice in opposite directions at right angles. The furnace should be allowed to remain some weeks, after setting up, before it is used ; and before raising a strong heat, a gentle fire should be sometimes kindled in it, the strength of which may be gradually increased. When a strong blast is expected, it is necessary to bind the brick work together, externally, by strong iron bars and plates, kept in their places by screws. The chimney should be nine inches wide, and raised to as great a height as circumstances will admit.

The coak of pit-coal is the only fuel fitted for exciting an intense heat, and should be used in all cases, except in the reverberatory, and in distillations with the sand bath, when pit-coal may be employed. The charcoal of wood is adapted principally to portable furnaces.

Pl. I.



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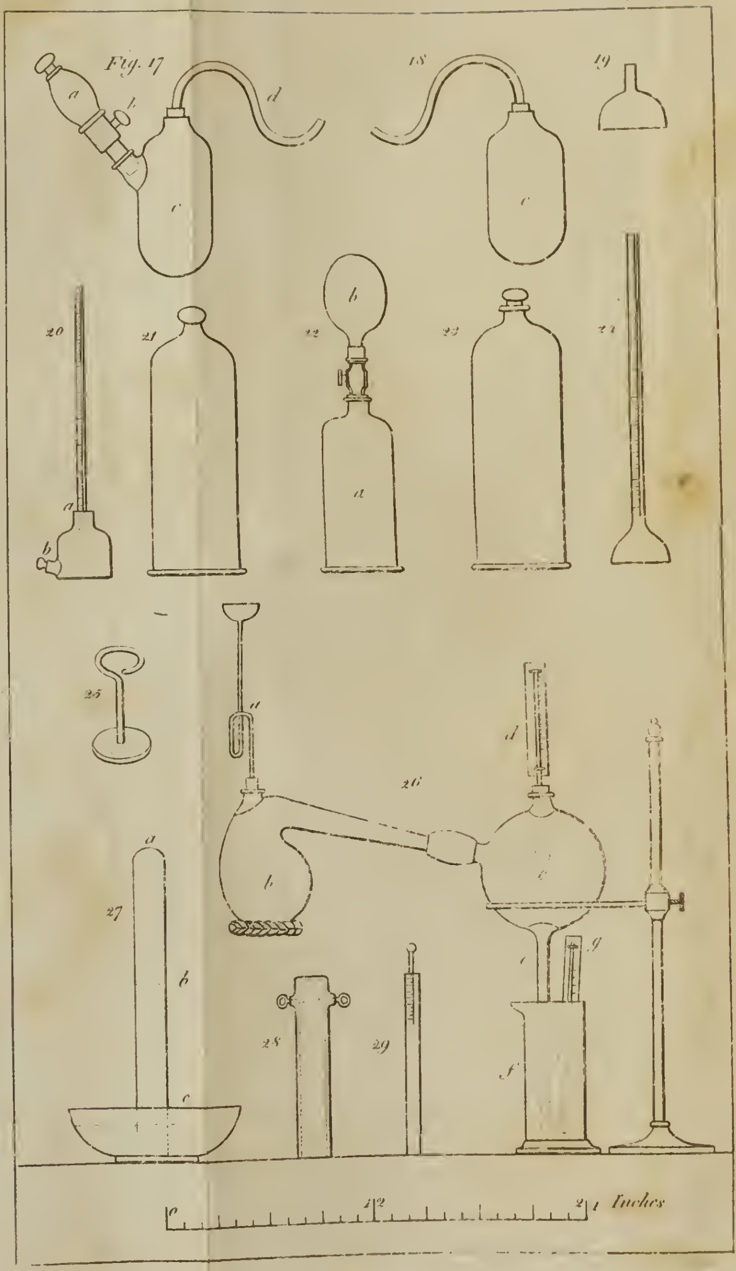

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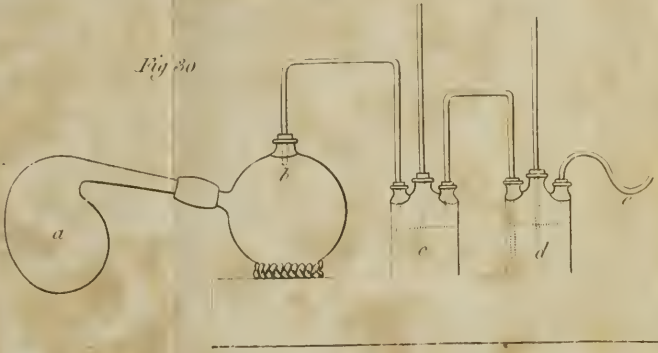
Fig 30



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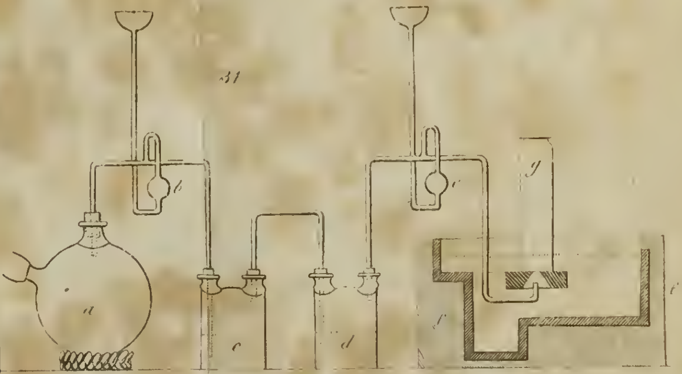

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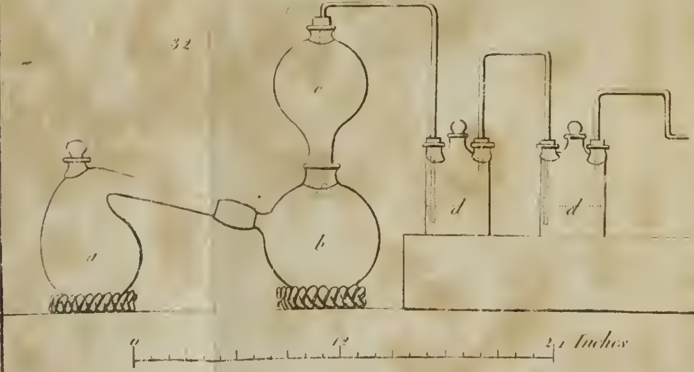

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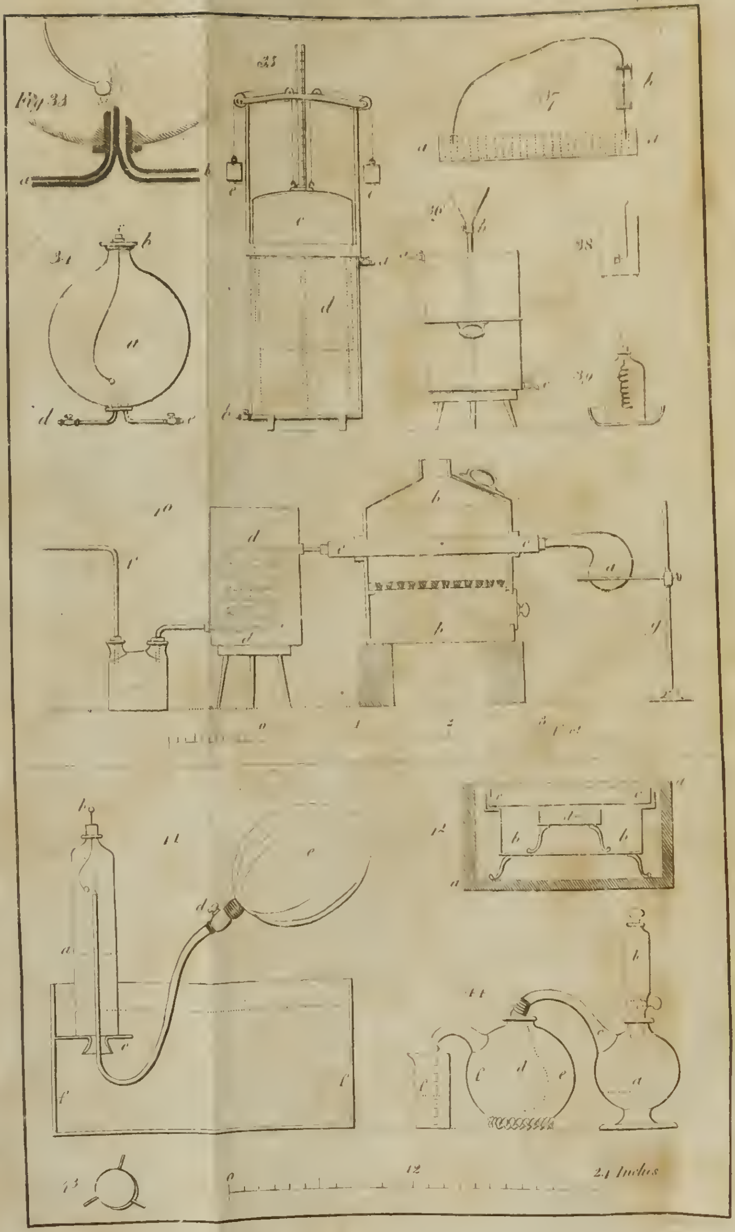

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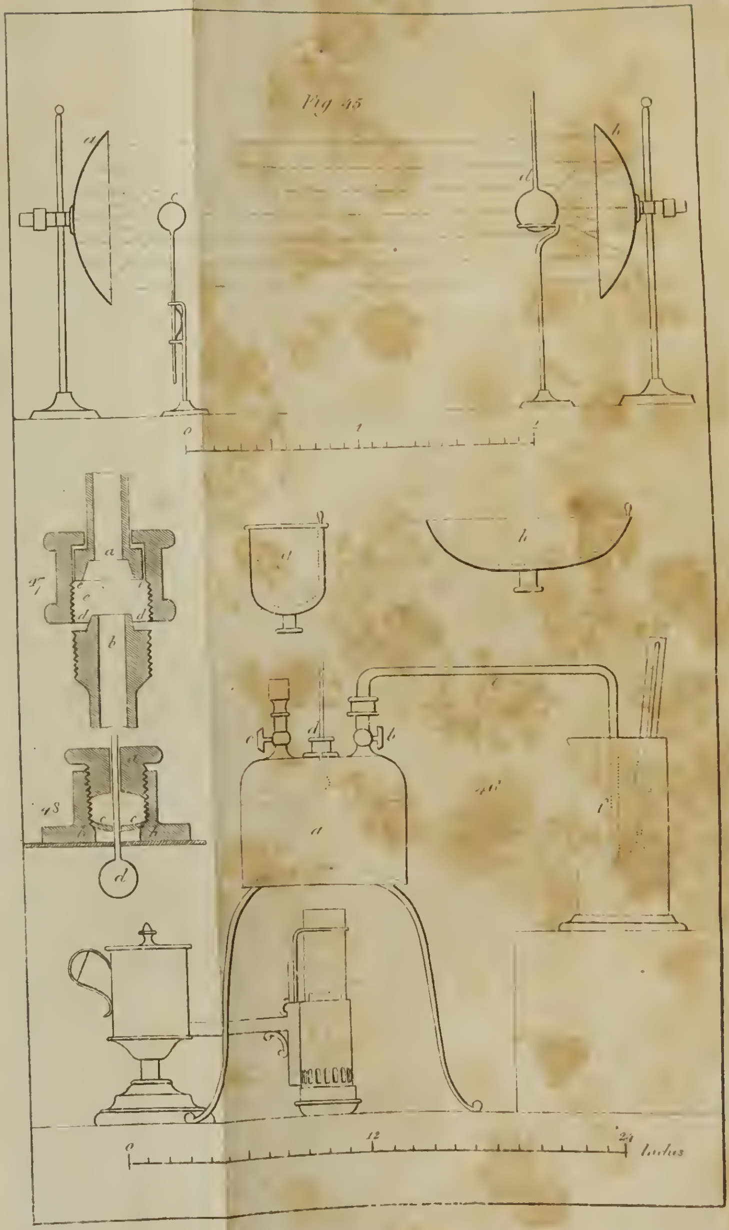

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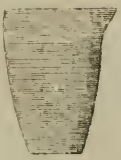
Fig. 49



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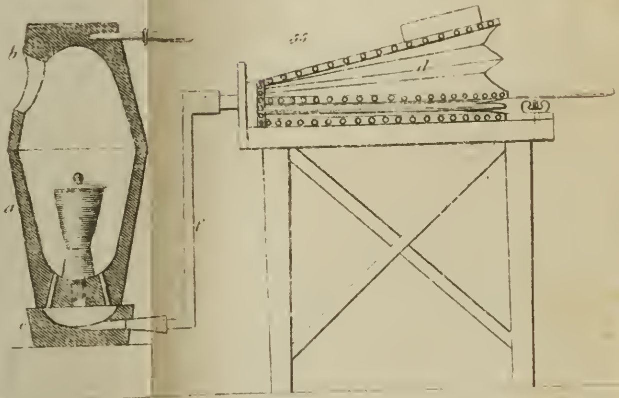

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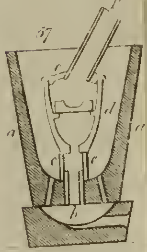

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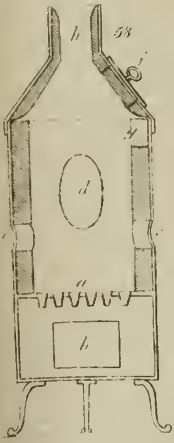

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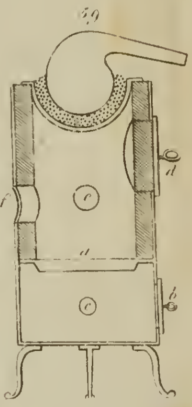

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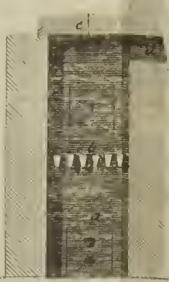
Fig. 60.



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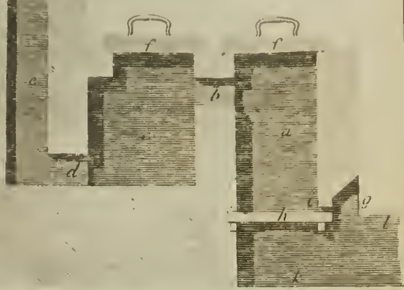

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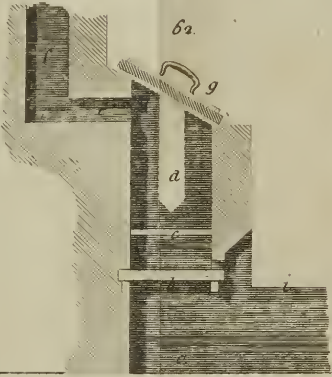

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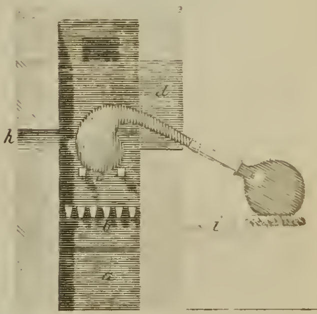

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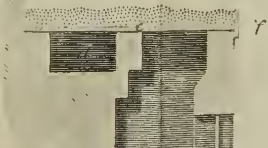

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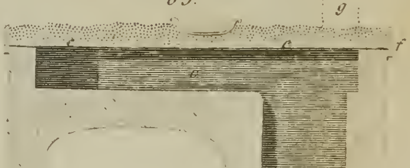

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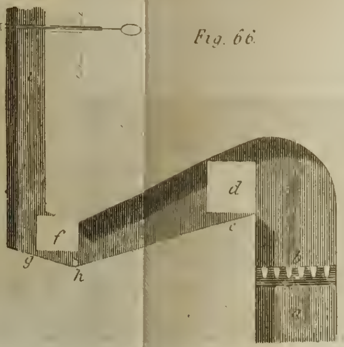
Fig. 66.



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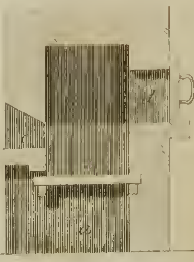

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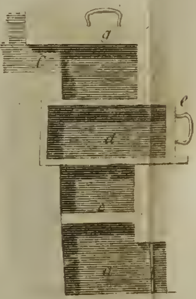

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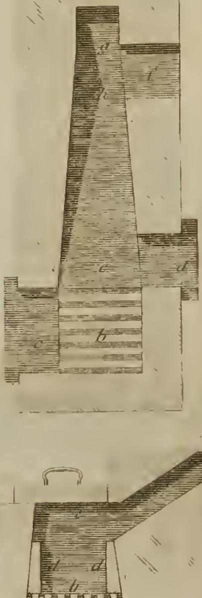

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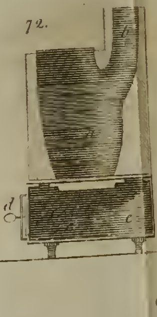

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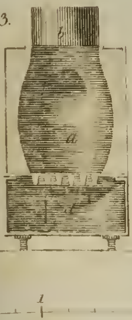

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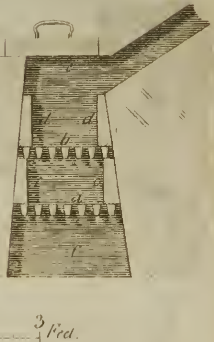

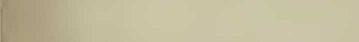

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NOTES

TO THE

FIRST AMERICAN EDITION

OF HENRY'S CHEMISTRY.

BY PROFESSOR SILLIMAN,

OF YALE COLLEGE.

Note 1. *Page* 10. *Introduction.*

THE argument which the author has so successfully urged with respect to his own country, admits of a still more forcible application to this. Chemistry is here almost a new pursuit, and hence it is not uncommon to find even intelligent men manifesting an entire ignorance of its nature and utility.

Happily the increasing taste for the science, which is indicated by our augmenting sources of chemical information, gives good grounds to hope that this species of knowledge will soon be extensively diffused.

Chemistry is at present publicly taught, in the University of Pennsylvania, at Philadelphia; in the College of New Jersey; in Columbia College, and in the College of Physicians and Surgeons, in the city of New York; in Yale College, at New Haven; in Dartmouth College, at Hanover, New Hampshire; in Harvard University, at Cambridge; and we are informed, that provision is making for introducing this science into the Colleges of South Carolina and Georgia; not to mention occasional courses of popular lectures delivered in our large commercial towns. Possessing, as the United States do, a very extensive territory, embracing every variety of surface and of internal structure, the greater part of which is scarcely explored, there can be no doubt that important sources of individual and national wealth are yet to be opened, by chemical and mineralogical enterprise.

We must regard it as not less a national reproach, than it certainly is a national loss, that most of the products of the chemical arts are imported into this country from Europe. It would be easy to establish this position by an extensive induction of particulars. It may be mentioned, however, that our own potashes are exported to Europe, and there in a great measure manufactured into glass, which comes to us for the supply of our houses, while we have sand, (the other ingredient of glass) in abundance. It is true, we have now several manufactories of glass, but they attempt little beyond the coarser productions of the art, and afford nothing like an adequate supply of these.

Till lately, not a pound of sulphuric acid (oil of vitriol) could be procured except from Europe; most of our pigments and medicines are derived from the same source, and most of those who compound and vend, and too many of those who administer the latter, are ignorant of their chemical properties. At this moment not a vessel of porcelain is manufactured within the United States, and it is not easy to procure even a stone bottle, of domestic manufacture, which is impervious to the united pressure of fluids and condensed gases.

Under such circumstances it is easy to see, that the practice of chemistry, even for philosophical purposes, must be attended with difficulties of no small magnitude; but those very difficulties prove more conclusively than any mere reasonings could do, the absolute necessity of promoting chemical knowledge, and it may be confidently affirmed, that until intelligent chemists are trained up at home, and induced to attempt the introduction and extension of the CHEMICAL ARTS, the United States will never attain to that pinnacle of national superiority, which Great Britain and France owe more to the *successful cultivation and application of natural science*, than the one does to the prowess of her armies, or the other to the triumphs of her marine.

The limits of a note will not allow of that ample illustration of this subject, which is due to the great interests of this country, as connected with chemical science and chemical arts. On no subject whatever, is extensive national and individual patronage more needed than on this, and no where would it bring a more ample individual and national reward.

Note 2. Page 3. Furnaces.

Dr. Black's furnace was admirably adapted to the purpose which he had principally in view, which was the exact regulation of the heat; but it was very inconvenient for many operations, and wholly inapplicable to others of much importance. It has been recently so far modified in London, as to deserve the name under which it is sold, by Mr. Accum, of the universal furnace, for, with it, every chemical operation (in the small way,) may be performed. In the mean time, the principal purpose of its inventor is frustrated; but still, if a single furnace were to be selected, it should undoubtedly be this.

It may be useful to those for whom these notes are intended, and probably to others, to know that furnaces sufficiently good for most chemical operations, may be procured in New Haven. Mr. Lyon will do the iron work, and Prime and Bradley, will make the fire brick and line them. A furnace constructed of thick sheet iron, of a cylindrical form, of about ten or twelve inches diameter in the clear, with two holes, one in each side, for the convenience of placing a tube across the furnace, with a chimney issuing out of the side, near the top, and furnished with an iron pot, let into the top, for a sand heat, is such an one as our workmen will execute with little difficulty. It will answer all very important purposes of private experiment, and if furnished with a support made by two perpendicular iron bars, attached to feet like those of andirons, connected at bottom by a cross bar, and adapted to iron staples fixed in the sides of the furnace, so that this last may slide up and down upon the iron rods, and be fixed at any particular height by thumb screws, it will be found highly convenient.

The iron pots for the sand heat may be procured at Salisbury, Stafford, and every other place where hollow ware is cast, and the expense of the whole need not exceed ten or twelve dollars.

Note 3. *Page* 6. *Evaporating Vessels.*

The want of apparatus is a principal difficulty with beginners, and especially in this country, and it will therefore be one object of these notes to point out simple contrivances by which these difficulties may be obviated. The author has in several parts of his work (page 67, line 16, &c.) alluded to some practices which will now be described more minutely.

The bottom of a broken retort or flask answers very well for an evaporating bason. The broken part may be removed by scratching the glass with a file, at the place where we wish it divided, and then applying a red hot iron to the place, till a crack is formed, which will follow the hot iron quite round, and may thus be led any where at pleasure. Another method is to tie a string, moistened with oil of turpentine, around the glass, and to set fire to it, holding the glass so that the flame may play on the line where we wish the division to take place; on applying cold water the glass will separate unless very thin. In this manner, a broken bottle may be converted into a plain or a tubulated air jar, according as the top or bottom has been broken; a retort's neck into a funnel or tube, and its bottom into an evaporating bason. A ragged edge may be removed from broken glass, by filing it or even cutting it with a pair of shears, *under water.* It is very material that it be under water.

Does this fluid, by its vis inertiæ, counteract the vibrations of the glass, arising from its elasticity, and thus render it less liable to fracture? Does the fact that water greatly facilitates the cutting, filing, or grinding of glass, whether immersed in, or merely moistened with that fluid, arise from any chemical, or merely from a mechanical action?

Note 4. *Page* 9. *Lutes.*

Finely powdered and sifted quick lime, with the white of an egg, forms an excellent lute. It must be applied with celerity, as it soon hardens. This lute will confine corrosive vapours, and endures most degrees of heat below redness very well. The best way of applying it, is to break one end of the egg, and as the white is beginning to run out, let it fall upon the part of the instrument to which the lute is to be applied. If carefully managed, the white will merely hang from the aperture in the egg, without separating, and by turning the instrument, it may be applied all around. Then, reversing the position of the egg, the remaining part of the white will run back into the shell, and may be kept for farther use. The lime may be applied by laying the instrument upon it, and turning it round and round, till it adheres at every part.

Note 5. Page 11. *Blow-Pipe.*

The hydrostatic blow-pipe of Mr. Robert Hare, junior, in which the stream of air is propelled by a column of water, is much more convenient than the common table blow-pipe. A regular blast is maintained for a long time, while the operator is perfectly at liberty, nothing more being necessary than occasionally to give a few strokes with a lever. See Mr. Hare's Memoir, Tilloch's Magazine, and Annals of Chemistry.

Note 6. Page 11. *Bending Tubes.*

Glass tubes may be bent in a common fire, or over a chafing-dish of live coals, and the angle is even more correct, and the tube less liable to break than when they are bent at the blow-pipe. With the aid of tubes and corks very good gas bottles may be fitted up from common vials and flasks. The corks should be perforated with a red hot iron. A convenient instrument for this purpose, may be procured at the blacksmith's. It is merely a tapering rod of iron, two or three feet long, one third of an inch in diameter, at one end, and quite pointed at the other. It should be furnished with a handle of wood, or a ring of iron, to hold it by. This will save much time and trouble in the adjustment of gas bottles. A little bees-wax, rubbed upon the tube, at the place where it is to be inserted into the cork, and warmed at the moment of insertion, insures the tightness of the juncture.

Note 7. Page 13. *Crystallization.*

Crystallization belongs to a great number of bodies. It is the act by which their particles arrange themselves into regular forms, reducible to some of the known mathematical figures. It is owing to the exertion of homogeneous affinity, or the attraction of aggregation. Solution by means of a menstruum, or fusion by means of caloric, is an indispensable preliminary to crystallization. In the former case, it is necessary to drive off part of the solvent by heat; in the latter, merely to allow the fluid to cool, in order that crystals may be formed. Certain circumstances are, however, necessary to be attended to in order to success. If the solvent be very rapidly expelled by the aid of a high temperature, or, if the fused body be suddenly exposed to an intense cold, either a shapeless mass will be formed, or only confused and irregular crystals. In general, fine crystals are obtained only by slow evaporation and by slow cooling. Water and most of the metals are examples of bodies that crystallize by a mere reduction of temperature; the salts are crystallized by diminishing the quantity of the solvent, that is, by evaporation, or by conjoining both of these principles, diminishing the solvent by evaporation and reducing the temperature; or, when a particular portion of a salt has been suspended by the aid of an elevated temperature, a simple reduction of temperature is sufficient, without evaporation. For, an elevated temperature increases the power of most solvents. Common salt, however, is dissolved in nearly equal quantities by cold as by hot water. No advantage is gained, therefore, in dissolving this salt, by the aid of heat, nor does a reduction of temperature cause it to crystallize. The only method in which this can be effected, is to diminish the quantity of the solvent. Hence the salt boilers crystallize this salt over the fire, by boiling away the water; on the contrary, a solution of nitre, made with heat, is suffered to cool, in order that it may crystallize. In both these cases, however, the fluid which remains may be made to afford more crystals by farther evaporation, until it is all dissipated.

The pressure of the air appears to favour crystallization; for, when a saturated solution of the sulphate of soda is made at a boiling heat in a matrass, and a cork inserted while it is still boiling, so as wholly to exclude the atmosphere, the solution will remain fluid on cooling; but on withdrawing the cork it will crystallize, especially if a crystal of the same salt have been dropped in, from which the crystallization may begin; for, it is found that crystallization is much facilitated by supplying a nucleus; and Le Blanc, a Parisian apothecary, has even founded upon it a method of obtaining large and beautiful crystals.

In this example of the sudden crystallization of the sulphate of soda, we may notice also the developement of caloric, which is in this particular case sudden and evident, and always takes place during crystallization, although the process is commonly so slow, that the rise of temperature is scarcely perceptible.

An increase of bulk is commonly an effect of crystallization, but sometimes the bulk is diminished, as in the case of mercury. Substances which have been deposited from an aqueous solution, always retain, intimately combined, a portion of water, which is called their *water of crystallization*. The efficacy of freezing mixtures is owing, in a considerable degree, to this water of crystallization, which, by becoming fluid, absorbs caloric. When the water of crystallization causes the salt to become fluid, with the aid of heat, the salt is said to suffer the *aqueous fusion*. When the water of crystallization escapes spontaneously, in consequence of exposure to the atmosphere, and of the attraction of the air, the salt is said to *effloresce*, for the crystalline form is destroyed, and the salt falls into powder. When the salt attracts water from the air, and becomes more or less fluid, it is said to *deliquesce*.

All bodies in crystallizing assume a determinate form. Thus the crystal of alum is an octahedron; that of common salt a cube; of the beryl, a hexahedral prism, &c. It must not be understood, however, that these forms are invariable. The same substance will sometimes assume one form, sometimes another, according to circumstances. But, to this *apparent* caprice there is a limit, for a given substance will always crystallize in one of a given number of forms, which are appropriate to it. What is the ultimate power which produces these remarkable effects, we are ignorant, but certain laws by which it operates have been recently developed, and have conducted to conclusions both singular and interesting. What had been conceived by Romé de L'Isle, and Bergman, has been ably demonstrated by Hauy; and it is proposed at this time to give the outlines of his theory of crystallization. It was intended, also, to give the figures necessary to demonstrate his ideas; but circumstances having rendered this inconvenient, reference may be had to the figures in Thomson and in Murray, and in Rees's Cyclopedia, and to the more extended accounts there given of Hauy's theory. Those who would see it in all its details and applications, may refer to Hauy's Mineralogy, vol. i. ii.; the Annals of Chemistry, vol. xvii.; Philosophical Magazine, vol. i. and Nicholson's Journal, vol. ix. 8vo.

The accounts here given, will be sufficient to elucidate the subject to those who hear the lectures for which this work is adopted as a text book, and the demonstrations which are given in connection with the lectures, from the models of crystals, will render figures less necessary.

Hauy has demonstrated, "*that in every crystallized substance, whatever may be the difference of figure which may arise from modifying circumstances, there is, in all its crystals, a primitive form, the nucleus, as it were, of the crystal, invariable in each substance, and by various modifications, which he points out, giving rise to the numerous secondary or actually existing forms.*" The lapidaries have long known that the crystals of the precious stones can be divided or split only in certain directions, and that they split in those directions with smooth faces. It was the observation of a similar fact which led to the theory of Hauy. He remarked, that an accidental fracture of a hexahedral prism of carbonate of lime, presented a very smooth surface. The fracture had happened obliquely from one of the sides to the base, so as to cut off one of its edges. The surface had so much lustre, that it seemed to be a natural layer or joining, and this induced Hauy to attempt to divide it still farther. This he was able to effect by applying the blow of a hammer to a knife, so placed, that the new fracture was parallel to the former one. He now tried the next side of the prism by the same means, but this proved refractory, and no division could be effected. The next side to this, divided as the first had done, with a smooth surface, making the same angle with the base. The next side proved refractory, but the next to that manifested the same structure with the first and third. From this statement, it appears that every other side, viz. in this case, the first, the third, and the fifth, was divisible in the same manner, the plans formed by the respective sections making the same angle with the base. Reversing the position of the prism, Hauy next attempted to divide it at the other end, beginning on the side which he had first separated with the knife; but he now found this, in its turn, refractory; the next, however, which at the other end had resisted the knife, now yielded to it, and thus the sections were continued on the alternate faces, until there was no face which had not been divided at one end or the other.

The hexahedral prism had now become a solid with fourteen faces. The bases had become triangles; the sides pentagons, and in place of the edges at the bases, were six trapeziums, three at one end and three at the other. Continuing the sections on all the sides, by fractures parallel to the former ones, the bases wholly disappeared. The solid was now a figure of twelve pentagonal sides. The sections being still continued in the same manner, the lateral pentagons became triangles, and the solid of twelve sides was now bounded by six lateral triangles and six pentagons. Finally, the divisions being continued as before, the lateral triangles disappeared and the figure became a rhomboid.

So singular a result induced him to attempt a similar dissection with other crystals of carbonate of lime, and however various were the figures of the crystals, he found them all reducible to the rhomb, which he therefore considered as the primitive crystal of all the carbonates of lime.

The same method being tried with the crystals of other substances, it was discovered, that by finding the natural joinings of the respective layers, a primitive form might be extracted out of all of them, which was, in most instances, different from the actual form of the crystal. This primitive form is always the same in the crystals of the same substance. Thus, the primitive form of the fluate of lime is an octahedron; that of the sulphate of barytes a prism with rhomboidal bases; of corundum, a rhomboid somewhat acute; of the beryl, a hexahedral prism; of the Elba iron ore, a cube; of felspar, an oblique angled parallelopiped, but not rhomboidal; of blende, or the native sulphuretted oxide of zinc, a dodecahedron with rhomboidal sides. It is not true, however, that crystals of every kind have been subjected to this mechanical analysis. Many of them have been, many others are not susceptible of it, because they are too soft or too brittle, or for some other reason not affecting the principle. But, from the striæ evident upon many of these crystals, indicating that they would divide only in a certain direction, and from the relation subsisting between their different secondary forms, Hauy finds reason to conclude what their primitive forms are. Had it not been possible, for instance, to split the dodecahedron of the carbonate of lime, consisting of two hexahedral pyramids, its primitive form could have been readily discovered by mere ocular inspection; for the rhomboid can be seen distinctly lying in the middle of the crystal, so evident are the striæ. This crystal, however, is very divisible, and the primitive form may at once be extracted by a few strokes of the hammer and knife. Hauy defines the primitive crystal to be "a solid of a constant form, inserted symmetrically in all the crystals of the same species, and the faces of which observe the direction of the layers which compose these crystals."

Only six primitive forms have been hitherto discovered; viz. the parallelopipedon, including the cube, the rhomb, and all other solids, bounded by six faces, parallel two and two; the regular tetrahedron; the octahedron with triangular faces; the six sided prism; the dodecahedron with rhomboidal faces; and the dodecahedron with isosceles triangular faces.

Thus far the theory, or rather the developement of facts must be admitted as wholly satisfactory. But Hauy does not stop here. The mechanical analysis may be carried still farther. The primitive crystal may be always divided by sections parallel to its different faces, and even in other directions. Were the dissection to be continued, by divisions made on all the sides at once, with the separation of layers of equal thickness, it is obvious that no change of form would be effected *ad infinitum;* e. g. a cube would still be a cube, and so on. But a division may be made parallel to some one side or more, and not to the rest; for instance, a hexahedral prism may be supposed to be divisible through all the diagonals of its bases, each one of which diagonals is parallel to two sides and no more. In this way it would be divided into six equal triangular prisms, and the prisms, joined again by their faces, would compose the original six sided prism.

Now, this figure is one of the primitive forms, and we see that it may be made up by other forms very different from itself, and different from any of the other primitive forms, and these forms may be developed by continuing the sections by lines parallel to one face or more, but not to all. Moreover, if the primitive form be divisible, in some other line not parallel to either side, it will be clearly possible that we may find it composed of forms different from itself. Thus, if a cube were divided through both its diagonals, on any one side, it would be reduced to four triangular prisms, and these prisms, if joined by their faces, would again compose the original cube. If the division were carried through all its diagonals on the different sides, the cube would then be resolved into twenty-four oblique tetrahedra, and these tetrahedra, joined again by their faces, would compose the original cube.

It is not pretended that the analysis, by dissection, has been carried to this extent. It is certainly conceivable, however, supposing it possible to operate on such small masses of matter, that it may be pushed so far, that no change of form beyond the given one would ensue, without resolving the substance into its original elements. To these last particles, the ultimate term, not only of actual but of supposable dissection, the name of *integrant particles* has been given by Hauy. So far as experiment has gone, they are three, viz. the tetrahedron, the simplest of pyramids ; the triangular prism, the simplest of prisms ; and the parallelopipedon, the simplest of solids, whose faces are parallel two and two. Of these three integrant particles, it is believed that the six primitive forms of crystals are composed. We have already seen how they may unite so as to produce forms very different from themselves ; and if we consider that they may unite in different ways, by their edges or faces, we shall find no difficulty in admitting that they are fully competent to produce the six primitive forms.

As it is often asked by those to whom this theory is new, why the integrant particles are not considered as the primitive forms, and why we stop at these last, since they are all reducible to the three integrant particles ? it will be useful to remark, that we have no evidence that the integrant particles, by uniting with each other in various ways, produce any more than the six primitive forms. The number of forms of crystals is, however, very great, and it happens only in a few instances, comparatively, that the actual form is the primitive. The truth seems to be, that the integrant particles first unite and produce the primitive form ; this is the first step in the production of a crystal.

The primitive form is the nucleus, the kernel, as it were, from which the crystal grows, and this primitive form is generated by the union of the integrant particles, either by their faces or edges. The additional matter which envelopes the nucleus, and forms the mass of the crystal, is composed of thin layers or slices, consisting of integrant particles, deposited upon the faces of the nucleus, so as to form laminæ parallel, in every step of the progress, to these faces. In the aggregation which takes place upon the surfaces of any given primitive form, we are not to consider the additions as composed necessarily of masses similar to the solid already produced, but of integrant particles only. In a word, the integrant particles first produce the primitive form, and then, beginning upon this as a substratum, they build up the crystal, that is, the actual or secondary form. But how is the vast variety of secondary forms produced from so small a number of primary forms? They arise from the abstraction of one or more rows of particles from the sides or angles, in the several layers of superposition, thus giving rise to the various modes of decrement which Hauy includes under several laws.

1. Decrements at the edges.
2. Decrements at the angles.
3. Intermediate decrements.
4. Mixed decrements.

The first of these laws admits of easy illustration. Suppose a cube upon which we wish to construct a secondary form. It may be effected in the following manner. Suppose a layer of integrant particles to be added to any one side of the cube, but stopping short of the edge by one row of particles all around. It is obvious, that in this manner a kind of step will be formed, and the new layer will not cover the whole of the side, but leave one row of particles uncovered, at the edges. Now, suppose the next layer to fall short of this by one row of integrant particles, and each successive layer to be deposited in the same manner and with the same decrement, till at last the layer shall consist of only a single particle. In this manner, a four sided pyramid will be erected on one side of the cube. Suppose the same process to be repeated on each of the six sides of the cube. It is apparent that, in this manner six pyramids will be produced, each of which is bounded by four triangles, and as the rate of decrement was uniform on each side of the cube, the planes of the pyramids, on the contiguous sides, will form one continued plane, viz. two equal triangles will be united and form a rhomboidal face, and as there are twenty-four triangles, there will, of course, be twelve rhombs. The solid will then be a dodecahedron, bounded by rhomboidal faces, a figure not at all analagous to the primitive form with which we began.

If we were now to reverse the process, we may extract the primitive form by chipping off with a knife the successive layers, till the six sides of the original cube should be again brought into view. It will not be necessary to go through a minute illustration of the other laws. It will be sufficient to state them somewhat more fully. The decrement which has been described, is obviously parallel to the sides of the primitive form. It is plain, that a decrement, commencing with the omission of a single particle at the angle; then of three, immediately contiguous, in the next layer above; then of five in the next above that, and so on, would be a decrement parallel to a diagonal of the face of the primitive form. This, then, is decrement according to the second law, that is decrement at the angles and parallel to the diagonals. Were it to go on regularly at all the angles at the same time, the secondary form produced, would be a regular octahedron, (Thomson, 2d edit. vol. iii. p. 220.)

The third law differs from this only in one circumstance. The subtraction is supposed to be made by commencing with a single particle at the angle, as before; but instead of going on in a line parallel to the diagonal, the subtraction becomes parallel to a line intermediate between the diagonal and the side; and this is effected, by making the subtraction in the proportion of one particle in the line parallel to one side enclosing the angle, and of two particles in the line which is parallel to the other side enclosing the angle, so that the decrement is really an oblique one, being parallel neither to a side nor to a diagonal, but to an intermediate line, and hence its name of intermediate decrement. In the fourth law of decrement, whether it be parallel to the edges or angles, the abstraction is not by one row of particles in breadth, or by one row in height, but by two or more rows in each of these cases. Hauy denotes this decrement by a fractional expression, where the numerator denotes the number of rows of particles which constitute the decrement, and the denominator the thickness of the lamina.

All the varieties of crystals may be explained by the application of these four laws, and the various modifications of which they are susceptible. These modifications are reducible to seven heads.

1. Sometimes the decrements take place on all the edges, or on all the angles, at once.

2. Sometimes on certain edges, or on certain angles only.

3. Sometimes they are uniform by one, two, or more rows.

4. Sometimes the law varies from one edge to another, or from one angle to another.

5. Sometimes decrements on the edges and angles take place at the same time.

6. Sometimes the same edge, or the same angle, undergoes several successive laws of decrement.

7. There are cases where the secondary crystal has faces parallel to those of the primitive form, and which give rise to new modifications, from their combinations with the faces resulting from the decrements.

An immense number of forms of crystals may exist with such a diversity of laws, and the possible forms far exceed the actual. The carbonate of lime, for instance, confining the calculation to two of the simplest laws, is susceptible of 2044 different forms, the subtractions being by one or two ranges; if three and four ranges be admitted, the possible forms will amount to 8,388,604, whereas the forms really known are only about 40. Such are the outlines of the theory of Hauy. As it has not been demonstrated, and perhaps, from the nature of the case cannot be, that crystals are actually formed in this manner, we must regard it as a mathematical hypothesis, depending for proof upon the ample manner in which it explains the phenomena, and the exact correspondence of calculation with fact, the theory having been applied successfully by its author in predicting the chemical constitution of substances from the form of their crystals, thus anticipating the accurate results of analysis.

Note 8. *Page* 14. *Nitrate of Copper.*

For the preparation of nitrate of copper, the common copper coin of this country (the cents) will answer perfectly well; and if they be battered into a roll by holding them upon an anvil with pincers, and striking them on the side with a hammer, they may be introduced into a gas-bottle, and a double product of nitrous gas and of nitrate of copper may thus be obtained.

Note 9. *Page* 23. *Elastic Gum-Bottle.*

The valve mentioned in the text, although convenient, is not indispensable, for the air of course returns into the bottle as soon as the ball is blown and the tube withdrawn.

In using this instrument, it is well to fix the tube into a perforated cork, and this into the mouth of the elastic bottle, making it secure by a string tied tight around.

Note 10. *Page* 38. *Boiling Point in Vacuo.*

This is now stated at 145° lower than the ordinary boiling point of the particular fluid, (Thomson, 2d edition, vol. i. p. 369.)

Note 11. *Page* 38. *Influence of Pressure on Ebullition.*

These principles may be illustrated very pleasingly, in the following manner.

Provide a flask with a stop-cock cemented to its mouth. A common straight stop-cock thrust through a cork, and firmly prest into the mouth of the flask, will answer the purpose. Introduce as much water as will fill about one third or one half of the flask. Place it on live coals in a chafing-dish, and when it boils rapidly, shut the cock. Immediately the ebullition will be checked, and in the progress of a few seconds, it will nearly or quite cease. Remove the vessel from the fire, and open the cock ; the accumulated vapour, which repressed the ebullition, will then rush out with great violence, and the fluid will boil very rapidly. This experiment requires caution, lest, from continuing the heat too long, the flask should burst ; and it will, therefore, be well to prove the strength of the flask by degrees ; but the beginner must not venture too far.

Again, while the water is boiling freely in the flask on the fire, shut the cock and remove the vessel into a cool place. Although at a distance from the fire, the boiling will continue for some time ; it may be for a quarter or half of an hour. During this period, if the flask be immersed in cold water, a rapid ebullition will be produced ; if in hot, it will be repressed or entirely destroyed. Lastly, if a flask with a very long neck be tightly corked while it is boiling, and after it has become cold be suddenly reversed, the water in it will fall down the neck with the apparent weight of a stone ; for it now falls without any resistance from the atmosphere.

This instrument, or one constructed on this principle, with some variation of form, is called the *water-hammer*.

Note 12. *Page* 39. *Vaporation of Ether.*

The experiment is not striking unless the water be hotter than 104°, in which case it becomes unpleasant to immerse the hands in it.

Perhaps the following method is better. Introduce some ether into a small vial ; tie the neck of a bladder fast around the neck of the vial, and introduce the latter into water at the temperature of 150° or 200°. Within a few seconds the bladder will be fully distended by the vapour of the ether, as much as it would be by a vigorous inflation from the lungs, and some of the ether will disappear from the vial. On withdrawing this from the water, the bladder soon becomes flaccid, and very rapidly if dashed with cold water. Water may be vaporised in the same manner, only substituting a small flask for the vial, and immersing it in hot mercury instead of hot water.

Note 13. *Page* 51. *Gazometer and Air-Holders.* [See Frontispiece.]

An instrument has been for several years used in the laboratory of Yale College, for experiments in the large way, on the gases which water does not rapidly absorb, which has been found to be more convenient and complete than any other arrangement of apparatus for similar purposes. The only instrument of the kind which has ever been constructed, was manufactured in New Haven. Being calculated for an extensive course of public lectures, delivered in a laboratory where there is plenty of room, its dimensions are larger than might be worth while in establishments on a smaller scale Its form is that of a parallelopipedon, 7 1-8 feet long, 3 feet wide, and 2 feet 2 inches deep, without allowing for the two inch pine plank of which this part of the instrument is constructed. The several planks and parts are connected by grooves and tongues, and bound together by iron rods, passing laterally through them, and terminating in screws furnished with nuts. The interior part is furnished with two shelves, [see Frontispiece AAAA.] each two feet six inches long, for sustaining air-jars and bell-glasses ; the middle space between these is one foot eight inches wide, and forms a well [see Frontispiece H.] for immersing the bell-glasses ; across this well is placed a sliding shelf, [see Frontispiece G.] with three inverted shallow tin funnels beneath it, corresponding with as many holes for receiving and transferring gases. Thus far, it is obvious that the instrument is only a very extensive pneumatic cistern, and has no superiority over those commonly in use, except from its affording ample space for a very important and interesting class of experiments, which are much more impressive and convincing to a large audience, when performed on a large scale. There are, however, a number of additional contrivances. Beneath each of the shelves are two inverted rectangular boxes, [shewn in Frontispiece by dotted lines at H. under AAAA.] made of thin pine plank, dovetailed together at the angles, entirely open below, and attached to the inferior side of the shelves by tongues, grooves, and wood-screws. These boxes are twelve inches deep, of the capacity of about 12 gallons each, and occupy the whole space beneath the shelves except 7,5 inches at each end of the cistern, and nine inches between the bottom of the boxes and the bottom of the cistern. This latter space is reserved to give room for the action of three pair of hydrostatic bellows. [See Frontispiece BB.] They are made of leather, nailed to the bottom of the cistern, distended by circular iron rings, and attached by nails to a thick circular plank which serves as a top, and which is moved up and down by an iron rod connected with an iron lever, [see Frontispiece CCC.] which rests on a forked iron support, attached to the upper edge of the end of the cistern. The bellows are so placed, that nearly one half projects beneath the boxes, which we may call reservoirs; the other part is beneath the open space which lies between the end of the reservoirs and the end of the cistern, and the rod of the bellows perforates the shelf immediately at the termination of the box and contiguous to it, but does not pass through the box, which must be air-tight. At the edge of that part of the bellows which projects beneath the reservoir, is a valve opening upward; in the centre of the bellows and on the bottom of the cistern, which is also the bottom of the bellows, is another valve opening upwards, covering an orifice which is connected with a duct, leading out, laterally, through the plank, edgewise, to the atmosphere. Into this duct is inserted a copper tube, [see Frontispiece DD.] consisting of two parts, one of which forms merely a portion of the duct, being driven into it so that it forms a perfectly tight connection; the other part is soldered to this at right angles, and ascends in close contact with the outside of the cistern, till it rises two inches higher than its upper edge, and there it opens in an orifice somewhat dilated. Each of the four reservoirs may be considered as furnished with the apparatus of bellows, duct, valves, and tube; although in the instrument to which this description refers, there are in fact but three bellows, &c. one reservoir being destitute of them. It remains to be remarked, that each reservoir is furnished with a stop-cock, which lies horizontally upon the shelf and partly imbedded in it, and passes into the reservoir by a short tube of copper, soldered at right angles with the cock. The cocks of the two contiguous reservoirs are placed parallel to each other and to the sides of the cistern, and immediately contiguous to the partition which separates the reservoirs, and they are connected by a third stop-cock soldered to each of them, opening into both by proper orifices, and thus serving, when occasion requires, to connect the reservoirs, and in fact, to convert two into one. Through each of the shelves, at the angles of the two reservoirs which are contiguous at once to that side of the cistern which may be regarded as its back part, and to the well, a hole is bored into the reservoir for the insertion of a copper tube for a blow-pipe. These tubes are so formed, that while one part is pressed firmly into the hole so as to be air-tight, another part, at right angles with the first, and bending in a pretty large curve, terminates in a trumpet-like orifice, adapted to the insertion of a cork. Immediately beneath these two orifices is a table, attached by hinges to the side of the cistern, to sustain a lamp for the blow-pipe; when not in use, it hangs by the side of the cistern, and is raised occasionally as it is wanted.

To an intelligent chemist, it will be obvious from an attentive perusal of the description, that this instrument will afford all the following advantages.

1. It is an extensive pneumatic cistern, with every common convenience, on a large scale.

2. By the bellows and their appendages, common air may be thrown into the reservoirs, by which means the height of the water on the shelves may be increased at pleasure, when it is too low.

3. By permitting a portion of this air to escape, by opening one of the horizontal cocks, the height of the water on the shelves may be diminished at pleasure ; thus we have means of graduating the height of the water precisely to our purpose without lading it out or in.

4. We have four capacious air-holders in the very place where the gases are produced, viz. in the pneumatic cistern ; thus, four different kinds of gases may be stored away under water in a space otherwise useless. For instance, common air, for regulating the height of the water, or, for the blow-pipe, may be in one reservoir ; oxygen gas in a second, hydrogen gas in a third, and olefiant gas in a fourth, and they may be thus reserved for future use.

5. The gases may be drawn off for use into bell-glasses, merely by bringing those bell-glasses, filled with water, over the horizontal cocks.

6. It is obvious that the four reservoirs are in fact four large gazometers ; they want nothing to entitle them to this character, except a scale which a moderate share of ingenuity would easily adapt to them; the gases may be delivered into them at once by crooked tubes passing from the gas-bottles, and any gas contained in a bell-glass may be thrown into a reservoir, by a single stroke of the bellows. For this purpose a crooked tube connected with that which leads to the bellows and terminating in the well beneath an air jar, is all that is necessary. Or, by baring the arm, the gas may be thrown up by the hand, into the reservoirs, the jar being pushed down through the water.

7. It affords an excellent blow-pipe for common purposes noticed in a former note, and for the fine experiments with oxygen gas ; and, by fitting to it Mr. Hare's very ingenious apparatus of the silver cylinder, it becomes the *compound blow-pipe* for the invention and application of which he deserves so much credit. By the same contrivance water is formed with the greatest facility by burning the two gases as they come from their respective reservoirs, and issue at a common orifice, covering the flame with a receiver.

8. The inflammable gases being confined beneath the pressure of water, will issue at any orifices, where they are permitted, and thus all the ornamental as well as useful purposes to which the combustion of these gases is applied, may be exhibited ; particularly, the gas from fossil coal may be made to burn in revolving jets, stars, and other fanciful and useful forms, merely by substituting for a blow-pipe tube, the apparatus proper for this exhibition.

All these purposes, this instrument has fully answered during several years ; and it may be confidently recommended to lecturers on chemistry, and, on a smaller scale would be very valuable to a private chemist. A forcing pump might be substituted for the bellows, with a saving of the space which the bellows occupy, but it would be probably less convenient in practice.

This first idea of this instrument was suggested to the writer while in Philadelphia by Mr. Hare's compound blow-pipe. Being mentioned to that gentleman, the subject was prosecuted in common, and so far matured that it was afterwards executed by the annotator. (See Mr. Hare's communication on the subject in the transactions of the Philosophical Society of Philadelphia. The details of the instrument, of which a plate is there given, differ however considerably from that which has now been described.)

Note 14. *Page* 95. *Acid Tests.*

As litmus cannot be usually procured in the shops of this country, it will be well to mention that the infusion or tincture of almost all the blue or purple flowers and vegetables, will answer sufficiently well. The blue violet, the blue lily, and especially the blue or purple cabbage being boiled with water in a tea-kettle afford an infusion, which when filtered or strained forms an excellent test of acids. The purple cabbage is particularly recommended, both because it is a good test, and because it can be procured at that season of the year when there are no flowers. It is also an excellent test of alcalies which turn it green. A very pleasing succession of colours may be exhibited by this infusion.

1. Acids turn it red.

2. Alkalies, if added in such proportion as merely to saturate the acid, restore the purple colour.

3. A little more alkali turns it green. The reverse order may be pursued beginning with the alkali and ending with the acid. The infusion of the skin of the blue or purple radish is a good test, and that of the leaf of the red beet an indifferent one. All these infusions may be preserved from putrefaction by the addition of common spirit, but, they ultimately lose their colour. Indigo is not changed by acids or alkalies. It is even dissolved in the sulphuric acid, for the purposes of dyeing.

Note 15. *Page* 96. *Charcoal.*

Charcoal may be neatly prepared for exhibition, by plunging pieces of wood, held by tongs, beneath a quantity of melted lead. In this case there can be no access of air, and the wood will, if the pieces be small, be converted, in a few minutes, into charcoal, while the lead will be thrown into violent ebullition, by the escape of the water, hydrogen and other volatile parts. The hydrogen is so abundant, that it may even be set on fire as it issues from the lead.

Note 16. *Page* 107. *Carbonate of Soda.*

It is the solution of this salt combined with a prodigious quantity of carbonic acid forced into union with it and retained by strong mechanical compression, which constitutes the *soda water*, so much used in England, for acidity in the stomach and other complaints.

Note 17. *Page* 116.

The author means fossil coal; charcoal is also commonly called coal in this country, and, although it affords abundance of gas by distillation, it gives no tar. In obtaining the carburetted hydrogen gas from fossil coal, it is indispensable that the vessel be not nearly full of the coal; otherwise it will be in danger of bursting on account of the inflated state into which the heat throws the coal.

Note 18. *Page* 119. *Crystallization of Sulphur.*

The crystallization of sulphur is easily effected by melting it in a deep earthen vessel, and pouring out the part which remains fluid, by piercing a hole, near the edge of the vessel, in the crust which forms on the surface, when the instrument is withdrawn from the fire.

Note 19. *Page* 128. *Sulphate of Lime.*

In this country the sulphate of lime, under the name of the plaster of Paris is extensively used, as a manure, and is constantly becoming more and more important to our agricultural interests. It is brought to the United States principally from Nova Scotia, and is a regular article of commerce in our sea ports, whence it is carried into the interior. What is the true theory of the operation of this salt as a manure ? This question has not, as yet, been satisfactorily answered. It cannot however admit of a doubt that the question is of much importance, as it could not fail to direct the application of this substance by principle, whereas, it is now left to empirical practice.

A common impression, that the effect is produced by the attraction of water, is manifestly erroneous, for this salt discovers very little disposition to attract water.

In order to a skilful investigation of this subject, plants should be made to grow in an insulated portion of earth, of a known composition, mixed with a given weight of the sulphate of lime, and, after the plant had arrived at maturity it should be accurately analyzed as well as the earth in which it grew, in order to ascertain,

1. Whether any portion of the sulphate of lime could be found in the vegetable.
2. If not, whether any portion of its elements, sulphur, oxygen, or lime could be discovered.
3. Whether the soil contained any portion of the salt undecomposed, or of its elements, and how much, and whether any new combinations of the salt, or of its elements, with any matter present in the soil or vegetable had been effected.
4. As a standard of comparison, other individuals of the same kind of vegetables, which have grown in an equal portion of the same soil, *unmixed with the plaster*, should be examined in the same manner, as well as the soil, after the plant had arrived at maturity.

By experiments of this kind sufficiently multiplied, and performed with the requisite care, we might hope to arrive at satisfactory results. If such experiments have been undertaken, the writer has not met with them.

There is another practical application of this substance, which is however not equally important. It is employed, after having been calcined and pulverised, to copy busts and statues, and even the countenances of living people. It is formed into a paste, which is applied to the subject; the paste soon hardens and forms a mould, in which a plaster cast exactly resembling the original may be formed. In this way the Plaster of Paris is highly important to the imitative arts, which have, without doubt, an intimate connexion with a highly improved state of society.

Note 20. *Page* 129. *Alum.*

Any salt containing potash or ammonia will effect the crystallization of alum. For this purpose it is well known that the manufacturers of alum add muriate or sulphate of potash, or putrid urine; this last contains ammonia. Alum has always an excess of acid. It may therefore be:

1. A supersulphate of alumine and potash.
2. A supersulphate of alumine and ammonia.
3. A supersulphate of alumine potash and ammonia.

It is usually a triple salt, and sometimes even quadruple. All these varieties are actually found in the alum of commerce, according to the various processes used for its crystallization.

Note 21. *Page* 141. *Nitrous Gas and Oxygen Gas produce Nitrous Acid.*

The generation of an acid is much more strikingly shewn by filling a wide tube, or narrow jar, with almost any blue vegetable infusion. Turn up a portion of oxygen gas, and no change will ensue. Add the proper proportion of nitrous gas; immediately deep red fumes of nitrous acid will appear, and the liquor will become red.

The nitrous acid appears to be a gas, when confined in a glass vessel, without the contact of any other body. This may be demonstrated in the following manner:

Let a glass bottle be ground with emery, into the mouth of another of twice the capacity. Fill the upper bottle with oxygen gas, in the usual manner, and the lower one with nitrous gas. Place the two bottles, as quickly as possible, in connection The gases will combine, caloric will be extricated, and the vessels will be filled with the red gas of nitrous acid, which may in this manner be kept for any length of time unchanged. On separating the bottles, and immersing their orifices in water, there will be an immediate absorption, and if a blue infusion have been employed, it will become red.

Note 22. *Page* 146. *Nitrous Oxide.*

If the gas be skilfully prepared, the precaution of letting it stand several hours over water seems to be unnecessary, and, it is very desirable to avoid it, because a pretty rapid absorption takes place, and much gas is thus lost. The writer has not hesitated to administer it for respiration within half an hour from its production, and sometimes immediately, and no unpleasant consequence has ever resulted. So far as nitrous gas is concerned, no advantage is gained by letting it stand, for if this be present, its proportion will rather increase from the more rapid absorption of the nitrous oxide. And indeed a very coarse trial is sufficient to decide whether nitrous gas be present, which will be detected by the smell and colour of nitrous acid which it will produce on mixing it with common air by turning up a jar. As to any vapour of nitrous acid which may have been extricated, this will, no doubt, be absorbed by the water, in the various operations preparatory to the respiration of the gas.

Note 23. *Page* 151. *Nitre and Sulphur.*

In the combustion of sulphur, by means of nitre, if only 1-6 or 1-8 of nitre be employed, the phenomenon will not be striking; the sulphur will scarcely burn unless in contact with an ignited body; for illustration, a larger proportion should be used.

Note 24. *Page* 158. *Acid Gases*, &c.

There is a method of obtaining the gases, which water rapidly absorbs, without the aid of a mercurial apparatus. It is founded on the difference between the specific gravity of these gases and that of common air.

1. Muriatic acid gas, whose weight is nearly twice that of common air, may be obtained as follows:

To the mouth of a Florence flask adapt a cork, in which is fixed a glass tube, bent twice at right angles. Place in the flask the materials for affording muriatic acid gas, viz. common salt and sulphuric acid, and having adjusted the tube, let one end of it be inserted into a narrow-mouthed empty bottle or vial, and let the orifice of the tube descend quite to the bottom of the bottle or vial. The muriatic acid gas, from its great weight, will occupy the lower portion of the vessel, and expel the common air at the mouth. Thus the gas will be obtained sufficienty pure for exhibiting its most obvious properties.

In the same manner precisely, the sulphurous acid gas and the fluoric acid gas may be obtained.

2. The ammoniacal gas, being lighter than common air, is to be obtained upon the same principle, only reversing the arrangement.

The materials for affording this gas, viz. quick-lime and muriate of ammonia being placed in a flask, instead of a tube twice bent, employ a straight tube passing, as before, through the cork. Invert the vial or bottle upon this tube, so that the orifice of the tube may be in contact with the bottom of the bottle, which is now its highest part. The ammoniacal gas will rise and expel the common air, as in the other cases, only the order will be reversed.

It may be decided when the vessels are about filled with the gases, by the pungency of the smell, by the mist produced by the muriatic and fluoric acid gases, at the mouth of the vial, and perhaps better than all by the copious white cloud which all the acid gases produce, when a feather, dipped in liquid ammonia, is brought to the mouth of the vial, or by the occurrence of the same phenomenon, in the case of ammoniacal gas, when the feather is dipped in muriatic acid.

Note 25. *Page* 162. *Muriate of Ammonia.*

This salt may be formed by mingling the constituent gases in a two-necked receiver, as they issue from two retorts, in the manner recommended by the author for the carbonate of ammonia. See text, page 107.

Note 26. *Page* 170. *Super-Oxymuriate of Potash.*

As caustic potash is expensive when purchased, and troublesome to prepare, it may be well for the student to know that the carbonate of potash, as commonly found in the shops, will do for the formation of the super-oxymuriate. In this case there is a continual effervescence, at least during the earlier stages of the process, owing to the disengagement of carbonic acid gas. Some silex is also deposited, derived from the potash which, as it is found in commerce, usually contains a portion of silex. One who had never observed the fact before, might mistake this for a deposition of the salt in question.

Note 27. *Page* 195. *Silver.*

The remark in the text, that silver, when dissolved in nitric acid, exhibits a green colour if impure, is strictly applicable to the alloy of silver with copper, such as exists in coin and in trinkets, which, when dissolved in nitric acid, tinge the solution green, but silver might be impure from a combination with various other substances, without giving, on that account, a green solution.

Note 28. *Page* 197. *Fulminating Silver.*

Pulverize 100 grains of the common lunar caustic of the shops (nitrate of silver ;) add to it one ounce of alcohol and one ounce of nitric acid. If these agents are good, there will be a violent action. But, this will not happen with these fluids as they are commonly found, and generally it will be necessary to apply a very moderate heat, which must be removed as soon as the action comes on. Very soon a thick white precipitate will appear ; distilled water may then be thrown on to check the action, if becoming too violent ; the precipitate must be washed in distilled water, after having been separated by the filter, or, by decantation, and will fulminate powerfully by heat or friction. A convenient way of exploding it is to place a grain or two of it on the blade of a knife, and to hold it over a candle.

Note 29. *Page* 198. *Boiling point of Mercury.*

This, according to the latest experiments of Irvine and others, is placed at 672° Fahrenheit. See Murray's System of Chemistry, vol. i. page 153.

Note 30. *Page* 198. *Nitrate of Mercury.*

The fact that the nitrate of mercury differs very much in its properties, according as it is prepared with or without heat, is extremely important. In the latter case, it will bear any degree of dilution with pure water, without decomposition, or affording any precipitate. In the former, a large portion of the oxide, still retaining a little acid, will be thrown down merely by the affinity existing between water and the nitric acid. For this reason, the nitrate of mercury, made with heat, cannot be employed in the analysis of mineral waters, and in many other analytical operations, because water alone will produce a precipitate, and this will give a false indication of the presence of some foreign body.

Again, when muriatic acid is united to the oxide of mercury made by the nitric acid, *with heat*, corrosive sublimate is produced; when to that made *without heat*, calomel is the product. This alone demonstrates the necessity of attending to this distinction; for few bodies so similar in their composition, are so different in their properties, as corrosive sublimate and calomel. The truth is, that when the solution of mercury in the nitric acid is made *with heat*, the metal is oxydized to a maximum; when without heat, to a minimum only, and this is the cause of the widely different properties which the two solutions exhibit, and of much of the confusion which is found on this subject in chemical books.

Note 31. *Page* 213. *Sulphuret of Iron.*

There can be no doubt that the author perfectly understood that the phenomenon of the extrication of latent caloric, attended by light, during the combination of sulphur and iron, is not, as he has termed it, a *combustion*. Were it a real combustion, the iron would be found oxydized, and the sulphur acidified. But neither of these facts is so. It is well known that the compound decomposes water by the aid of an acid, and sulphur rises dissolved in the hydrogen, both of which facts are inconsistent with a previous combustion. Whatever uncertainty there may be, (and it is acknowledged there is much) in the use of the word combustion, it must, no doubt, in every case, include a combination of oxygen with the body burned, and an increase of weight in the sum of the products, neither of which facts exists in this case.

Note 32. *Page* 216. *Oxides of Lead.*

The observation in the text, that "the oxides of lead give up their oxygen on the application of heat," is not true in the extent there stated. A portion only of its oxygen can be obtained from the *red oxide*, which contains the most. If the flame of the blow-pipe be directed upon red lead in a platina spoon, it immediately becomes the yellow oxide by losing a portion of oxygen, and then melts into a glass, and cannot, by any longer continuance, or increased intensity of heat, be reduced to the metallic state; but the addition of any carbonaceous substance immediately effects it, under the blow-pipe.

Note 33. *Page* 240. *Gallic Acid.*

The due regulation of the heat is very important in this method of obtaining gallic acid. A moderate sand-heat is sufficient, and the retort must be removed from the fire at the moment when a dark coloured oil begins to rise, or before, because this oil will redissolve, or greatly contaminate the crystals of gallic acid.

Note 34. *Page* 241. *Iron.*

Iron is not always, *immediately*, precipitated black by the gallic acid. If it be in a low state of oxygenizement, the colour will scarcely be perceived at first; but on agitating the fluid in contact with the air, it will become purple, gradually inclining to black, owing to the absorption of oxygen.

ADDITIONS

TO THE

SECOND AMERICAN EDITION

OF HENRY'S CHEMISTRY.

BY PROFESSOR SILLIMAN,

OF YALE COLLEGE.

Page 185. *Physical Properties of the Metals.**

THE physical properties of several of the metals are not inferior, in importance, to those depending on their chemical relations, and those of the greater number are interesting and instructive.

I. THEIR WEIGHT AND DENSITY. The heaviest earthy body (sulphat of barytes) does not weigh 4, 5—water being 1.

Platinum, the heaviest of the metals weighs 23.—Gold 19, 25.—Mercury 13, 56.—Lead 11, 35.—Silver 10, 47.—Iron 7, 60. A tabular view of this subject is exhibited by the author in an appendix. The principal uses of the great weight of the metals are : 1. in war, where their projectile force, in the form of balls, far exceeds that of any other bodies. In ancient war, stones were used for the same purpose, but, their force was vastly inferior, especially as they were thrown by machines and not by gun powder. 2. as a moving power, especially in balances and scales and in all other instances where a great power, in a small bulk, is wanted : 3. in the reduction of the metals themselves from their ores ; after fusion they subside to the bottom, and leave the earthy impurities on the top.

II. OPACITY. The metals are commonly said to be *perfectly* opake ; without doubt they are by far the most opake of all bodies, but, as gold leaf transmits a beautiful green colour, and silver leaf appears white, when held up to a window, is it not probable that if the other metals could be reduced to the same thinness they also would transmit light ? Tinfoil however, completely intercepts the light, although much thinner than common writing paper which is partially transparent.

III. LUSTRE. This property appears to depend on the two preceding, and, although it is not peculiar to the metals, it is possessed by them in a most eminent degree, as is beautifully exhibited, in gold, silver, mercury and polished steel. It is true that mica or isinglass, several of the feldt

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* In the remarks which are here made upon the physical properties of the metals no notice is taken of the newly discovered bases of the alkalies of several of the earths and of two of the acids, because, these bodies, although some of them bear a strong analogy to metals, have not been long enough known to make it proper to admit them, as yet, into a systematical classification.

spars, and some other earthy compounds exhibit, in their natural state, a considerable degree of brilliancy, and the marbles, alabaster, the gems and most very hard stones can be made to assume it in a high degree by polishing; but, if a furrow be made by scratching any brilliant body which is not metallic, it will appear dull; on the contrary, if a bright metal (not an ore) be scratched, the furrow is equally brilliant as the original surface. Mica is sometimes mistaken for metal, but, it may always be distinguished in this way. The brilliancy and opacity of metals fit them admirably for mirrors of which they are always the basis; in consequence of their opacity, they intercept the light, and, by means of the high polish which they are capable of assuming, they throw back or reflect all the rays; hence bright metals do not become heated except with extreme slowness.

IV. Metals are the most perfect conductors of electricity, heat and galvanism, and, when moistened with acids, or other agents, that act powerfully on them, and placed in a particular order, they generate galvanism more rapidly than any other bodies.

V. Fusibility. There is a very great diversity in the fusibility of the metals; quicksilver is always fluid at atmospheric temperatures, except in high polar latitudes; but as it can be frozen at—39°, by artificial cold, as well as by the natural cold of Hudson's bay, and of Siberia, it must be regarded merely as a melted metal.

Platinum can be softened, but is not fusible in our common furnaces, although it will melt under a stream of oxigen gas, directed on to burning charcoal. Mercury is therefore at the bottom of the scale, and, (if, we except perhaps some of the newly discovered and very refractory metals,) platinum is at the head. Between these extremes there is a very great variety; some, as iron and manganese, require a full white heat, or, the greatest heat which a wind furnace can produce; some, as silver, copper and gold, a full red, or low white heat; several, as lead, tin, bismuth and zinc melt from 442° to a low red heat, (Aikin's dict. ii. 96), and there are metallic alloys which will melt even below the heat of boiling water. Melted metals retain their brilliancy and opacity, unless tarnished by the atmospherical oxygen; their surfaces assume somewhat of a convex form, especially at the edges;—this is owing to the cohesive attraction of their particles, and hence, when dispersed in small masses, they become globular, and readily run together again, when brought into contact. For the same reason the hand is not wetted by being plunged into quicksilver.

The fusibility of the metals is of the utmost consequence, for, we are thus enabled, to cast them in moulds, into any form, and even to produce very beautiful figures and ornaments upon their surfaces, instead of resorting to the tedious labour of cutting vessels from the block by the chisel, or turning them in the lathe; operations, which, with respect to iron, the most important of all the metals, would be nearly impracticable. By slow cooling, after fusion, most of the metals may be made to crystalize; as soon as a crust is formed on the surface, it is broken, and the fluid metal within, poured out, when crystals are often found lining the inside. Some of the metals, as iron and bismuth, expand by congealing, as is proved by their floating on the melted metal, when any portions remain unmelted. Hence they take the impressions of the mould with great accuracy.—Arsenic is volatilized at a low temperature, and is therefore more prone to fly away in vapour than to melt.

Most of the metals can be volatilized by heat, and several of them are dissipated with great rapidity, by the solar focus and by electric and galvanic discharges.

VI. TENACITY. The tenacity of the metals is the source of some of their most important uses in the arts, but this property they possess in very different degrees. According to the experiments of Sickingen (Aikins' Dic. ii. 97.)

An iron wire one-tenth inch in diameter sustains	705 lbs. avoir.
Copper,	387
Platinum	351
Silver	239
Gold	191

"The tenacity of tin is greatly inferior to that of gold, and the tenacity of lead is least of all."

A lead wire one-tenth inch in diameter will not sustain 30 lb.

The tenacity of metals gives origin to two other properties considerably similar, yet really distinct, ductility and malleability.

1. Ductility is the power of being drawn into wire; this is done by causing cylindrical pieces of the metals sharpened at one end to pass through a series of conical holes, made in a plate of iron, beginning with the larger and going on to those which are successively smaller and smaller, till the wire is sufficiently fine.

2. Malleability is the property of suffering extension under the hammer or between the rolling cylinders. It might be imagined that the properties of malleability and ductility are exactly correspondent, but this is by no means true. Tin and lead are considerably malleable, but very imperfectly ductile; iron, in the cold, is scarcely malleable at all, but it is astonishingly ductile; it can be drawn into wires as fine as human hair, and perukes have actually been made of it; gold, silver and platinum possess both properties in an eminent degree. Gold is the most malleable of all the metals; notwithstanding its great specific gravity, it can be beaten into leaves so thin that the wind will blow them away, and silver is, in this particular, very little inferior. Gold, of the degree of thinness which it has in common gold leaf, requires but one grain in weight to cover 56 square inches, and it may be made much thinner still.

During the compression of metals either under the hammer, or between the rolling cylinders, caloric is evolved; iron, by rapid hammering, can be made red hot; it becomes brittle however as the other metals do, by similar treatment, and, to restore their flexibility they require to be slowly heated, or annealed; thus, iron wire is always brittle till it has been warmed, after which it may be bended without danger of breaking. It is obvious that the property of laminability, or, of being formed into plates or leaves, depends on malleability, while that of ductility *is in the compound ratio of the malleability and tenacity.*

To the tenacity of metals we are indebted for the utility of chains, anchors, wire and other similar mechanical contrivances, and to their malleability for all the wrought metallic instruments.—Intimately connected with these properties are those of hardness and elasticity, which are not possessed by metals in their natural state, in any remarkable degree. All the metals are scratched by many of the earthy bodies, and various earthy powders are made use of to polish them. Both elasticity and hardness, so indispensable to the most important uses of iron, are imparted in a great degree, by processes, the details of which belong to the history of the individual metals.—In general, however, they consist in heating the metal and cooling it suddenly, by which means, while it becomes harder and more elastic, it is rendered also more brittle; but, by heating it again and cooling it slowly, it may be restored to its former condition. Iron, possesses naturally, very little elasticity, but, by processes of art it may be rendered almost perfectly elastic, as in the balance springs of watches.—The alloys of the metals are sometimes much more hard and elastic than the metals which enter into their composition—for instance, tin and copper are neither hard nor elastic, in any remarkable degree, but, bell metal is highly elastic and considerably hard.

VII. Colour, taste, smell. The metals are various in colour, but generally their colours are shades of white, grey and yellow. (Murray iii. 29.) Most of them affect the organs of taste peculiarly, and rather disagreeably; as zinc and copper.—Some are nearly tasteless, as silver and gold.—A peculiar odour attends several of them when rubbed or handled, as arsenic, tin and lead, but these effects hardly admit of description.

Page 191. *Natural History of Metals.*

The metals are not presented immediately to the hand of man, like the objects of the animal and vegetable kingdoms, but, they are, for the most part, buried in darkness, in the bowels of the earth, where they are so much disguised, by combination and mixture with other substances, that they often appear entirely unlike themselves. Hence they are acquired only by slow and painful toil, and by noxious processes, and dangerous operations; their properties and uses have been but slowly developed, and it is to be regretted, that they are the most usual instruments of human destruction, and, because they are more or less the representatives of all other kinds of property, they have been made the immediate motives, means and objects, of the most sordid passions and the most flagitious crimes.

The metals are occasionally found, in nature, in the metallic state, but, more generally, they are combined with other substances, and, in this state, they are called *ores*. A metal, in this condition, is said to be mineralized, and the substance with which it is combined, is called the mineralizer. The principal mineralizers are oxygen, sulphur, arsenic, the carbonic, sulphuric, muriatic, arsénic and phosphoric acids, and carbon. As far as our knowledge at present extends, all ores may be included under one or another of the following descriptions:

1. Native metals, and alloys of one metal with another.
2. Native metallic oxides; or, compounds of the metals with oxygen.

3. Native metallic salts; or, compounds of the metallic oxides with acids.

4. Native sulphurets and carburets; or, compounds of the metals with sulphur or carbon.

Gold, silver, platinum, mercury, copper, bismuth, antimony and arsenic are frequently found native;—iron more rarely, and a few other metals have been reported to be found occasionally native. The native alloys exist principally between gold and silver, gold and copper, and mercury and silver. Arsenic, however, is a very common mineralizer, and exists, more or less, in a great proportion of the ores. Platinum is always found in the metallic state;—gold, most generally, and silver frequently.

The metallic oxides and sulphurets constitute by far the most extensive and important classes of ores. In the state of oxide the metals are brittle, " have an earthy appearance and exhibit different colours, but have no lustre. Iron, cobalt, copper, arsenic, bismuth, antimony, zinc, manganese, tin, lead and mercury exist in this condition." (Schmeisser ii. 14.)

Metals, combined with sulphur, are also brittle, but, they frequently have the metallic lustre. The compounds of iron and sulphur are called pyrites; the same name is applied to compounds of sulphur and iron, containing copper, or arsenic, and the first description is called ferruginous—the second cupreous, and the third arsenical pyrites.

Heat produces in the sulphurets a sulphureous odour, and in those which contain arsenic, as many of the pyritical ores do, an odour of garlic is produced by friction, percussion and heat. Silver, iron, lead, copper, mercury and antimony are often found combined with sulphur. (Ibid.)

The only metal whose combination with carbon is well understood is iron, in the substance, called plumbago.

The compounds of acids with metallic oxides are more rare than most of the preceding states; they appear differently, and some of them look much more like earthy substances, than ores.

1. Iron is found combined with the sulphuric, phosphoric and carbonic acids, &c.
2. Copper with the sulphuric, carbonic, arsenic and muriatic acids, &c.
3. Lead with the sulphuric, carbonic, arsenic, chromic, molybdic and muriatic acids, &c.
4. Zinc with the sulphuric.
5. Antimony with the muriatic.
6. Silver with the sulphuric, muriatic and arsenic acids.
7. Mercury with the sulphuric and muriatic acids.
8. Cobalt with the arsenic and sulphuric acids.
9. Manganese with the carbonic and phosphoric acids.

The ores constitute but a very small portion of this globe, at least of those parts of it which have been explored. They are never found in large extended masses, like those of granite, trap and limestone, but, usually, in cavities and veins, principally in the hardest rocks. These are often divided by fissures, running through them in various directions, the two sides of which frequently tally to each other as if they had been divided by some convulsion of the globe. It is in such fissures that the veins of metal are commonly found. They usually cross the strata at right angles, and, in most instances, are perpendicular or inclined to the horizon; rarely are they horizontal. The veins do not consist entirely of ore; the greater portion of them is, for the most part, filled with some kind of stony substance, different from the rock; it is commonly denominated spar, because it has often a crystaline or plated structure. Carbonat of lime or calcareous spar, fluor spar or fluate of lime quartz, amorphous and crystalized, and sulphate of barytes, or, ponderous spar, are the most frequent, and the latter more so than perhaps any other. The miners call these things the matrix or gangue of the particular metal; sometimes the metal is dispersed among the gangue, only in specks; at other times it prevails so as to occupy a considerable part, or nearly the whole of the vein. Although ores are sometimes found in horizontal beds, in plain countries, they are most abundant in mountainous and rugged regions. Granite and the other primitive rocks rarely contain ores, but gneiss and the schistose rocks contain them in abundance; limestone, quartz and barytic spars are well stored with them; they are not abundant in whin, and serpentine very seldom affords them.

There are perhaps few subjects on which mankind are more credulous than on that of the discovery of ores. Hence the numerous impositions practised on the ignorant and avaricious by artful and impudent knavery. It is now scarcely credible that implicit faith was once reposed in the *virgula divinitoria*, or divining rod as it was called, nor, should we have expected that the British Encyclopedia would have more than countenanced a folly which the good sense of mankind has long since discarded. Mr. Price an English writer on the Cornish mines, has very gravely informed us that; "hazle rods, cut in the winter do best, and that apple tree suckers, rods from peach trees, currants, or the oak will answer tolerably well."—The use of these rods was, that when poised in a particular manner in the hand, they would be attracted toward the spot of earth containing an ore. Mr. Price says that if a person with a divining rod in his hand stand with one foot advanced, and a guinea beneath it, and a half-penny beneath the other foot, the rod will be drawn towards the guinea, and that if the guinea be put into the place of the half-penny, the attractions will be reversed. This art once formed a distinct profession, and the same impostors pretended to be affected with convulsions, swoonings, lethargy, &c. when reposing on ground beneath which metals lay concealed It would hardly be proper to mention such ridiculous follies, were there not still some people in this country who have a strong leaning toward them. Much more confidence is reposed in certain indications, almost equally fallacious, such as the dreary aspect of a mountain—the sterility and nakedness of a country—the blighted state of vegetation, imaginary exhalations from the ground, and many other similar things. But, when metallic grains and fragments are found dispersed among the sand of a plain, or in the bed of a river, it is reasonably concluded that they have been detached by rains from the hills, and washed down by the water; when the springs of a country are contaminated with a metalline impregnation, there can be no doubt that ores are below. Above all, when a vein of metal appears at the surface, which not unfrequently happens on the steep side of a hill—a promontory, or the bank of a river, decisive evidence is obtained.

The fortunes of men ought not to be hazarded in mining speculations without all the certainty that the nature of the case will admit of, and this can frequently be afforded by *boring*, a simple and not very expensive operation, which is worth more than all the divinations and inchantments that have ever been practised.

MINES AND MINING.

After the existence of ore is ascertained, to the satisfaction of the adventurers, if the country be level, or nearly so, a pit similar to a well, is sunk; it is called a shaft, and if the earth be not sufficiently compact, the sides of the shaft are supported by planks and timbers; timbers are placed horizontally also, at convenient distances, and, upon these, ladders are firmly fixed in a perpendicular position, and a plank or two laid, at the foot of each, for a landing place; as the shaft goes down deeper and deeper, other ladders are added, in a connected series till the miners arrive at the ore. Having found it, they, of course follow the vein; this produces another excavation, at right angles with the shaft; it is called an adit, level, or gallery. If the mine be worked through a rock, there are, of course, natural walls, and a roof sufficiently firm; sometimes, the walls of the vein are of rock, while the roof is crumbly, and it must then be supported firmly by planks and timber. As the only inducement to excavate the gallery arises from the width of the vein, the gallery varies extremely in diameter;—at one place, where the vein has failed, or become very small, it is merely a narrow passage, where the miners can do nothing more than crawl through; at another, a man can walk erect, with ease, and, at another, it becomes a wild and lofty chamber. Sometimes the gallery is intersected by another vein, running off at an angle; here a new gallery may be formed, and thus the work may be indefinitely extended —A shaft is often sunk from the gallery already formed, to meet a new one below, and thus these subterranean passages are made to communicate freely with one another, and with the surface of the ground. When the mine is situated in a hilly country, it becomes easy to discharge the water, merely by continuing the galleries out, to the side of a hill; but, in a level country, the water must be raised to the surface. For this purpose, as well as for raising the ore, letting down people and implements, and for other similar objects, all the powers of mechanism are occasionally employed.

The strength of men and of animals; mills, worked by wind or water, and, above all, the steam engine, which is in general use in England, are employed to accomplish the desired object. In the Dolgoath mine, in Cornwall, a steam engine is employed to raise the water. The machine there employed works a rod composed of pieces of timber; it descends more than 1,000 feet into the ground, and raises the water to a superior adit, where it runs off through the side of the hill. There is another evil to which the miner is peculiarly exposed. Deadly gases, consisting chiefly of the carbonic acid gas, and some varieties of the hydrogen gases, occasionally suffocate him; and, when they are inflammable, which often happens in coal mines, they become mixed with the atmospherical oxygen; when the miners descend with lamps and candles to their work, the mixture sometimes explodes and blows the adventurers and their works into the air, or, hurries them with fatal velocity, along the narrow chambers of the mine. To prevent these evils recourse is had to ventilation. When the mine is situated in the side of a hill, and the galleries are continued out to the side, a ventilation is, of course established, because the mouth of the shaft and the outlet of the gallery are at different elevations; the air within the shaft is in winter warmer, and, in summer, colder than that above ground; thus, the two columns of air, the one of which pressess at the mouth of the gallery, and the other at the bottom of the shaft, are *rarely* in equilibrio, and therefore a current is established, one way or the other. It is observed, that about the equinoxes, these columns sometimes are so nearly in equipoise, (because the air without and within the earth, is then very nearly of the same temperature) that the miners perceive a stagnation, and, it becomes necessary to kindle a fire in order to destroy the equilibrium. When circumstances do not admit of a natural ventilation, as, where shafts have been sunk in a level country, it is accomplished by maintaining, at the mouth of one of the shafts, a constant fire, which discharges its heated air through a long chimney, and, thus the equilibrium of the, otherwise, equiponderant columns of the atmosphere is destroyed, and, a double current of foul air up, and of good air down is maintained. No work can be done in the mines, without artificial light, which enables the miner to see where the vein is richest in ore, and there he applies his hammers, crows, levers, pick axes, wedges, and other mechanical instruments to detach it from the rock. If, however, this be very hard, it is necessary to employ the force of gun powder; indeed this is more generally necessary, and, the explosions, (from their happening prematurely, or, from their driving fragments of the rock to a distance, and thus hitting those who imagined themselves out of danger,) are, not unfrequently fatal to the workmen. The great copper mine of Doigoath, at Redruth, in Cornwall, is a fair example to illustrate most of the particulars mentioned in this sketch.

Much labour and expense are saved when the ore is so situated that direct access can be had to it by a lateral excavation in the side of a hill or mountain. Then it is necessary only to penetrate into the ground, in a horizontal direction, till the ore is found, and thus, the same passage, which serves as an entrance, affords also a drain for the water, a gallery for the people to go in and out, and a road for the conveyance of the ore, which is transported to day light, on small hand sleds or waggons, drawn along the bottom of the adit; frequently, the miners are *harnessed* to these simple machines, as they find, from experience, that they work with more ease in this way. It is not possible however, to penetrate far into a mountain without ventilation. In pursuing the narrow passage of the gallery, the air becomes so much vitiated, by the respiration of the workmen, and by the burning of their candies, that, ultimately, their lights begin to burn dimly, their breathing becomes laborious, and every thing announces imminent danger. To obviate this, either a shaft is sunk from a higher part of the hill, to meet the adit, or, another gallery is made at a different elevation, and, the two are connected in the interior of the mountain, by a shaft, and thus, a ventilation is produced upon the principles already explained. In this description of mines, all the expensive and troublesome machinery calculated to raise the ore and the water, and, to let down people, implements, &c. may be dispensed with, and the business is wonderfully simplified.

Of this kind of mines, the ancient and celebrated ore, at Castleton, in Derbyshire, called the Owdin mine, is a fine example.

Page 191.—*Metallurgy.*

As a preliminary to the great and expensive processes for extracting metals from their ores in the large way, it is necessary to perform the same thing on a small scale, for the purpose of forming a judgment as to the profit which may be expected from the mine, and, indeed, this step ought always to be taken previously to the expenditure of any great sums in the mechanical operations of mining, otherwise, great loss may be sustained. These operations are called *docimasy* or the *docimastic* art; they constitute the assay, by which the quality and richness of the ore is judged of. The habit of examining minerals will soon enable a person, from the external appearance of an ore, to form a tolerably correct judgment of its nature and value. The blow-pipe will prove an important aid to his judgment, for, by means of this, assisted by proper fluxes, a judgment can usually be formed, in a few minutes, as to the kind of ore, although not as to the proportion of metal. A piece of charcoal or a spoon of platinum is commonly used for a support, to the bit of ore under examination, and, various additions of borax —sub carbonate of soda—black or white flux, microcosmic salt, &c. are made, according to the object in view. The blow-pipe is admirably adapted to the almost instantaneous production of a high and very manageable heat. As examples of its use, it may be mentioned that if a minute portion of the ore of cobalt be fused with borax, a fine blue button will be formed; if the proportion of salt has been too small, the button will appear almost black, but will become blue, on being diluted with more borax and fused over again. If borax be fused with oxide of manganese, a purple button will be formed; if this button be completely surrounded by the flame of the blow-pipe, and urged with a heat continued, for a few minutes, the globule will emit bubbles of gas and will become colourless; this is owing to the escape of oxygen gas which brings the manganese to the state of white oxide when it loses its colour. If this colourless globule, be heated again with the exterior flame of the blow-pipe, while the air has free contact with the globule, the purple colour will return; then by alternately repeating the first and second experiment upon it, the colour may be discharged and renewed at pleasure. Should these circumstances occur, the operator would, with good reason, conclude, that the first substance was cobalt and the second manganese. For minute instructions as to the use of the blow-pipe, reference may be had to Bergman's chemistry,

For practical purposes, the examination of ores is, however, commonly made in the assay furnace. Good, middling and poor specimens of the ore are selected, that the result may be neither too flattering nor too discouraging. The pieces selected, should be as free from the matrix as possible, and the stony matter may be still farther separated by breaking it with a hammer.

The ore is then pounded and the stony matters farther picked out; and advantage is taken of the difference in specific gravity between the ore and the matrix; they are agitated in water, or a stream is suffered to pass over them, when the metallic parts will sink and the stony fragments are washed away. A convenient quantity is then taken, varying from 100 grains to 100 pounds, according to the nature and value of the ore, and the degree of precision required; this is roasted, as it is called, that is, it is exposed, for a considerable time, to a low red heat, applied in shallow vessels. The object of this operation is to expel any sulphur or arsenic, which the mineral may contain; and, which it is, may be inferred, from the smell which is sulphureous in the one case, and alliaceous in the other. During this operation the metal is always converted into an oxide, and the object of the next process is to bring it to the state of a metal, by mixing it with substances which will, at once promote its fusion, and abstract its oxygen. These substances are called fluxes; they are numerous and various, and different fluxes are employed in reducing different ores, but, they usually contain carbon, as one ingredient, and some saline or alkaline substance; the former to abstract oxygen and the latter to promote fusion. The most common is the black flux, formed from 2 parts of tartar and 1 of nitre, mixed in a red hot crucible; this is well adapted to the ores of lead, copper and antimony. Another flux, well adapted to iron ores is composed of 20 parts of calcined borax, 10 of nitre and 2 of slacked lime, and these proportions correspond to 10 grains of the ore. Pounded glass 16 parts—borax 2, and powder of charcoal 1, answer the same purpose. Arsenic and nitre, in equal parts, form also a very active flux. With some of these or other fluxes a certain quantity of the roasted ore is heated in a crucible, and, at the end of the operation, the metal is found reduced, at the bottom of the crucible, forming a metallic button, whose weight, compared with that of the ore, gives the proportion of metal with sufficient accuracy to enable those concerned to decide on the expediency of prosecuting the adventure. This is however but a coarse analysis, if the object be to ascertain with correctness, the true chemical composition of the ore. But, in an economical point of view, it is, perhaps, even preferable to the more accurate methods, because it is of importance that the assay should, as much as possible, resemble the metallurgic processes in the large way, which must, necessarily, be performed with cheap materials and in a coarse manner, because the expense would absorb the profits were the costly re-agents of scientific chemistry introduced into the smelting and refining furnaces.

This method of examination is *via sicca*, in the dry way, as it used to be called. But, if we would ascertain the true composition of the ore, so as to give the specimen its correct place, in a system of scientific mineralogy, we must have recourse to the analysis, *via humida*, or, in the moist way, that is, not by fire, but by acids, alkalies and other re-agents. This method is now universally preferred by expert chemists, where science and not profit, is the object. Its processes however are tedious and require the utmost skill and patience in the analyst, and absolute purity in his re-agents.

An account of them involves details which would be misplaced among these general remarks, and more properly belong to the history of the particular metals.

After what has been said as to the manner of assaying ores, it will not be necessary to be very minute upon the operations of metallurgy in the large way, since the principles are almost identical, and the variations in the processes are produced chiefly by a reference to economy and facility of operation. The more general operations to which the ore is subjected, are *sorting, stamping, washing, reducing* and *refining.*

The sorting is merely the *picking over* of the ore, to free it from the matrix and other foreign bodies. In common cases it is entrusted to women and children, but, if there be several ores intermixed which it is necessary to separate, especially, if any of them be very valuable, as gold or silver, the sorting is then performed by skilful men, superintended by a master miner, or, captain of the mines.

The object of the stamping is to reduce the ore to moderately small fragments, in order to facilitate the farther separation of the matrix. For this purpose, it is pounded in stamping mills. They consist of perpendicular cylindrical pieces of wood, shod at the foot with iron, and worked by wind or water, or some other adequate moving power, which causes these great pestles to play up and down in huge stone troughs or mortars, containing the ore, while, in many instances, a stream of water, passing through the trough, washes away the lighter stony parts. The ore is always washed or dressed for the purpose of separating the stony fragments, and there are many ingenious methods of doing this, as, in the bed of a rivulet, on an artificial inclined plain over which water is made to pass; in tubs, boxes, &c. When there are grains, or minute fragments of very valuable metal, as for instance gold, dispersed among sand, the washing is performed on inclined plains, covered with cloth, which catches the angular and small pieces, that would otherwise be washed away. When the stony matrix is very hard, it is sometimes rendered friable, by heating it and throwing it, while very hot, into water, which causes it to crack.

The next object is the *roasting.* This is commonly performed in the open air, the ore being mixed with heaps of wood and exposed to a gentle red heat, a good while continued. Sometimes this operation is performed among charcoal, in furnaces of a particular form, contrived to save the arsenic or the sulphur as the case may be; they rise, in sublimation, and are condensed in some proper receptacle. Nitre is sometimes used to burn out the sulphur, but, is too expensive for common use. Some ores require several repetitions of the process of roasting before they are cleared of their sulphur and arsenic.

REDUCTION is the last and most important operation of the whole, to which the others may be regarded as merely preparatory. This is done in furnaces which vary exceedingly in size and form, according to the particular nature of the metal and the practice of different countries.

The great object is now to separate the oxygen, that the metal may appear in its proper character. For this purpose the ore is mixed with large quantities of fuel, commonly charcoal or coak, and a strong heat i raised;

the remaining sulphur and arsenic are expelled, and the oxygen, combining with the red hot carbon, flies away in the form of carbonic acid gas and gaseous oxide of carbon. Appropriate fluxes are also added to fuse any earthy matters which may remain, and sometimes, lime and alkali, and even some of the less valuable metals are added to absorb the sulphur more completely. At length, the metal, freed from most of its impurities, subsides to the bottom of the furnace, and the earthy and sulphurated mass floats as a scum or slag. This is sometimes drawn off at a convenient tap hole, or, by rakes, or, blown aside by the blast of bellows. The melted metal itself is drawn off by a tap hole at the bottom of the furnace, or, when the quantity is small, it is dipped out with ladles. The slag or scum is not always rejected. Sometimes, it is rich in some other metal, which, during the operation, has been oxydized and scorified, while that which was the principal object of the process, on account of its different nature, has not suffered the same change. The slag is therefore *occasionally*, and, in some particular cases, *usually* worked over by itself, and frequently yields no contemptible product. Sometimes it is very valuable of itself, as, in the extraction of silver from lead ores, where the oxydized lead forms a slag which is the foundation of the manufactures of litharge and red lead.

When volatile metals are to be obtained from their ores, it becomes necessary to employ a distilling apparatus, as, retorts of earth or iron; mercury and zinc are metals of this description.

The metals which have been obtained by the processes of reduction, although usually sufficiently pure for commercial purposes, are rarely so in a chemical sense; they are occasionally contaminated with some of the earthy matters with which the ore has been treated, and, they are often alloyed with other metals, some of which may be more valuable than the whole mass, or, which impair the proper qualities of the metal.

Last of all then comes the process of Refining, the object of which is to obtain the metal absolutely pure, or, at least, sufficiently so to answer all the purposes for which it is wanted. As, however, the processes for refining differ exceedingly, in the cases of the different metals, it is scarcely possible to give any general account of the subject. Such details belong more properly to the history of the particular metals.

The number of the metals is now nearly thirty. Most of them are of modern discovery. The ancients were acquainted with only seven, viz. gold, silver, mercury, iron, lead, tin, and copper.

Page 300. *On the Artificial Preparation of Mineral Waters.*

It is only within the last half century that a correct knowledge of the nature of mineral waters has been obtained. Their utility in a variety of diseases has been proved by the uniform experience of mankind from remote ages; even savage nations know that there is a very great diversity in the qualities and effects of different natural waters, and they are accustomed to make use of them for not a few of the same purposes that we do. The most powerful and celebrated mineral spring of this country, was known to the Indians in its vicinity, and they first pointed it out to the white people. Before the composition of mineral waters was understood, their efficacy was imputed, in a great degree, to a supposed fermentation in the bowels of the earth and to some volatile principles, too subtile to be detected by the art of man. The notions concerning them were visionary and fanciful, and bordered, not a little, on superstition.

It is not the least, among the attainments of modern chemistry, that more correct views of this subject have been acquired, and that the exact analysis of all the most celebrated natural mineral waters has led the way to their artificial formation, upon principles of science and common sense.

To the illustrious Bergman we are indebted for some of the earliest practical researches, and most useful directions on this subject. He analysed, with accuracy, several of the famous waters of Germany, and having discovered their contents, he applied himself with such ardour and success to effect their recomposition, that, in a short time, the prepared waters were introduced into the remotest provinces of Sweden. The dissertations of Bergman on these subjects should be carefully perused by all who are engaged in these pursuits.

Strictly speaking, all waters except rain and snow, and distilled waters are mineral; because they all contain, in a greater or less degree, mineral substances dissolved in them; even rain and snow water are not perfectly pure, and it may be doubted whether water ever is, unless distilled in glass vessels, for, water which has been condensed by the pewter worm of a common still gives a precipitate with sulphuretted hydrogen. In most natural springs and rivers, however, the proportion of foreign matter is so minute, as not materially to affect their sensible or chemical properties, and, it is only when this is the case that the term *mineral* is, with propriety, applied to a water.

Although there is a very great variety in the degree and nature of the impregnation of different waters, they are commonly included under a few general divisions, according to the kind and proportion of the ingredients which they contain.

They are either, 1. SALINE; 2. CHALYBEATE; 3. ACIDULOUS; or, 4. HEPATIC; the first, distinguished by the prevalence of saline ingredients, the second by iron, the third by carbonic acid, and the fourth by sulphuretted hydrogen. This division is rather loose, as these classes are often more or less mixed with one another, and there are a few substances of more rare occurrence, that are not included under either of them. It may serve however, as a guide in designating the principal varieties of operation that are necessary in forming the different sorts of mineral waters. It is almost superfluous to remark that a correct knowledge of the constitution of a mineral water must be attained before we can hope to succeed in preparing it artificially, and, the chemist must either perform the analysis for himself, or confide in that of some other person.

I. OF SALINE WATERS. The artificial preparation of this class of waters is the most simple and easy, although their analysis is often the most complicated and difficult. All that is necessary is merely to weigh out the different salts, in the proper proportions, and dissolve them in the water.

Some of these salts, are sold regularly in the shops of the apothecaries. Such are the sulphate of soda, (Glauber's salt) the sulphate of magnesia (Epsom salt) the carbonate of soda (sal soda) &c. The muriate of soda (common salt) is in every family. Sometimes these salts are sufficiently pure to be employed without any farther trouble, but, more generally, it will be necessary to redissolve and crystallize them anew.

There are some salts which are denominated *incompatible*, because they cannot exist in the same solution without mutual decomposition ; such are muriate of magnesia and carbonate of soda ; were a solution of each of these salts to be mingled, there would be an immediate precipitation of carbonate of magnesia ; and muriate of soda, alone, would remain in solution. Should any analyst imagine that he had discovered such salts in contemporaneous existence in a mineral water, he must of course conclude that his analysis is erroneous, and therefore, in any attempt to form an artificial water, he will be careful not to mingle any such inconsistent ingredients.

Some salts are not to be found in the shops, and therefore must be prepared on purpose. Such are muriate of lime and muriate of magnesia.—It is best to prepare these salts by adding the carbonates of lime and magnesia to muriatic acid diluted with one or two parts of water. For the former, marble powder should be used, formed by pounding in a clean mortar very white marble, of the granular kind, (if to be obtained,) and, if the powder have been previously exposed to a full red heat, till as much carbonic acid has been expelled as can be driven off in that way, it will dissolve with much more facility. Chalk may be used, but, this is apt to produce a very frothy and troublesome effervescence, unless the acid is largely diluted, when the action will be slow ; the same remarks are applicable to the carbonate of magnesia.—As the muriates of these two bases are very deliquescent and difficult to be crystallized, and, as they are prone, when very much concentrated, to become gelatinous, it is convenient to keep them in the fluid form, in close stopped bottles. A small portion may be measured out ; for instance, two gills, and evaporated to dryness, and the residuum weighed ; this will inform us how much solid salt is contained in any measured portion of the solution, and thus, much trouble may be saved, as the salts may be introduced into the water in the fluid form. There are a few salts occasionally found in mineral waters, which it may be adviseable not to introduce. Such is the sulphate of lime ; it does not possess any known medical efficacy, and it may be deposited in the system and create serious obstructions. For similar reasons, it is even doubtful whether the carbonate of lime ought to be added to artificial waters, at least in the proportion in which it is often found in native mineral waters ; for, as it is dissolved in them only by the aid of the carbonic acid *in excess*, it follows that, when this acid, by the warmth of the system, is expelled from the water, in the course of its circulation, the carbonate of lime may be deposited in some of the cavities and prove a troublesome impediment ; especially in the kidneys, the gall bladder or urinary bladder, and the ducts connected with them. The carbonate of magnesia is liable to be affected in a similar way, and, although these carbonates are, both, good correctors of acidity, and, in that way, useful in mineral waters, they may not always meet with an acid in the passages, which they may neutralize, and by which they may be carried off; if they should not meet an acid in the system, they would probably be deposited. Besides, their place, as antacids, is much more than supplied by carbonate of soda which is liable to none of these objections. In the composition of some mineral waters, it may therefore be adviseable to omit some of the ingredients and even to substitute others; for, we are not to presume that the substances which a mineral water has chanced to dissolve in its progress among the strata, are necessarily such, either in kind or proportion, as are best adapted to cure diseases, and therefore, it is clearly possible that a water of great utility may be formed without imitating any native mineral water. Such experiments however, ought to be directed by medical as well as chemical science.

Among the salts which have been discovered in mineral waters, the carbonates of lime, magnesia and iron;—the sulphates of soda, magnesia and lime; the muriates of soda, lime and magnesia, and the hydro-sulphuret of lime are the most common, and they are those with which we have most to do in the preparation of artificial mineral waters. Iron is almost the only metal of much importance found in waters; copper occurs, but more rarely, and it is not often that waters impregnated with it are used medicinally, as it is so poisonous to all animals.

II. Chalybeate Waters. Iron gives the character to this species of waters, and it is almost always suspended in them by the carbonic acid; it, sometimes, occurs combined with the sulphuric acid, but this fact is so rare that chalybeate waters are generally acidulous and sparkling, and sometimes they are very highly charged with the carbonic acid. The method of making a water chalybeate is simply this: very pure and clean iron, in the state of filings, is to be introduced in the proper proportion, into water charged, or, immediately to be charged with carbonic acid; the iron will be oxydized, in the lower degree, by the water, and then will be dissolved by the carbonic acid, and the more highly the water is charged with this acid gas, the more rapidly and in the greater proportion will it dissolve the iron. In estimating the proportion of the iron to be added to the water, we must allow only so much as, when combined with the oxygen and carbonic acid will equal the weight of carbonate of iron found, by analysis, in the water which we would imitate. A small quantity of iron imparts to water such decided properties that it is necessary to be very attentive to the proportion of iron. If the iron be in the higher state of oxygenizement, *it will not dissolve in the water* impregnated with carbonic acid, and, if, after solution by this acid, it be exposed to the atmosphere, the carbonic acid will principally escape; the iron will pass to the state of red oxide, and will be precipitated, a mere rust, and the chalybeate will thus be decomposed. It is therefore, for both these reasons, indispensable, that artificial chalybeate waters be prepared and kept in air-tight vessels. It is for the same reason that Bergman recommends introducing the iron filings in a small bag, and directs that when the bag is removed from the mineral water vessel, it should be immediately plunged into clean water, by which means it will be kept from passing to the state of red oxide; for, the rusting of iron in common cases, is effected by the joint action of water and the atmospherical oxygen.

The method recommended by Bergman of introducing an indefinite quantity of iron filings in a bag, I have found by experience not to be so good, as to put in the exact quantity of iron that is wanted, for more gives the water too high a chalybeate impregnation, and it is apt to become turbid, and to have a very disagreeable odour, like hydrogen, and, indeed, this smell probably proceeds from hydrogen, condensed in the water during its decomposition by the iron, for, the chalybeate waters are prone to have something of this odour. In some artificial chalybeate waters *sulphate of iron* is introduced instead of combining the iron in the manner that I have described. This is a great error, and, no person will ever, in that way, succeed in imitating the native carbonated chalybeate waters. The taste and other sensible properties, as well as the medical effects are very different. Whether an artificial chalybeate has been impregnated with the sulphate or carbonate of iron, may be easily decided by the same process which is applied to natural waters of these descriptions : viz. heat the water for a short time ; if it is a carbonate, the iron will speedily be deposited, in the form of a rust, and the water will no longer give the well known precipitates with the prussiate of potash and with gallic acid. But, if a sulphate of iron be present, there will be little or no deposite during the heating, and the fluid will answer to the above mentioned tests as well as before. When water is highly impregnated with carbonic acid, it acquires the chalybeate taste and other properties very rapidly ; the iron can be tasted within half an hour, after it is introduced, and twelve hours will produce a decided impregnation. Chalybeate waters are often more or less saline ; indeed they are usually so, and some of them are strongly impregnated with salts. There is no incompatibility between the carbonate of iron and the salts most commonly found in chalybeate springs ; it frequently exists in company with the earthy carbonates and sometimes even with the carbonate of soda. In forming a saline chalybeate, nothing more is necessary than to mix the salts, in the proper proportions, with the water, then to add the iron, and then inject the carbonic acid without delay, and to the intended extent.

III. Acidulous Waters. This is a highly interesting class of mineral waters, whose nature was entirely unknown till the discovery of carbonic acid assimilated them with the brisk fermented liquors, such as champagne wine, porter, cider, perry, &c., which owe their grateful pungency and briskness to the same cause. There is a very great difference in the proportion of carbonic acid existing in different mineral waters ; even common water contains a small portion, and there are mineral springs which are impregnated with two or even three times their bulk of this acid gas. It is the introduction of this gas which forms the most difficult and laborious part of the business of preparing artificial mineral waters. It is in this department, particularly, that modern improvements have attained a degree of excellence surpassing all previous conception, and producing results which have demonstrated that art can sometimes transcend the productions of nature.

Those who have not the means of doing better, may still practise the ingenious, although simple, processes of Bergman. The water to be impregnated with the carbonic acid may be introduced into a bottle, which should be quite full, and inverted in a proper vessel; carbonic acid, from a mixture of marble powder and dilute sulphuric acid, may then be passed up into the bottle, till about one third of the water is displaced; then, one hand being slid under the bottle's mouth, and the other placed upon its bottom, the bottle must be briskly agitated; an absorption will take place, the hand will be pressed fast to the bottle's mouth, it should be withdrawn under water, a portion of which will rush in to supply the void, and a repetition of this operation will soon saturate the water as far as it can be at the given temperature, and under the given pressure of the atmosphere. The water, thus impregnated, will have a mildly pungent and acidulous taste, and will sparkle when poured into a tumbler. The colder the water is, the more gas will be absorbed. If it is wished to add any saline ingredients; that can be done either before or after the impregnation with carbonic acid; and iron may be added to make it a chalybeate; for the acidulous waters are usually both chalybeate and saline. Although, by the means which have just been described, water can be impregnated as highly as it commonly is, in the natural acidulous waters, the impregnation may be carried much farther by peculiar contrivances and maniplations. I do not allude to the apparatus of Nooth or Priestley, which although elegant and showy, and sufficiently powerful for the experimental illustrations of a lecture, is altogether improper for operations on a large scale, and where it is desired to apply a great degree of force to effect the combination. The principal means by which water is charged with the amazing quantities of carbonic acid gas which are, now, introduced into it, may be reduced to three heads.

1. PRESSURE. 2. COLD. 3. AGITATION.—All these are combined in the most perfect manufactories of mineral waters, and some observations will be necessary on each of these heads.

1. PRESSURE. This is applied by means of strong forcing pumps which may be worked either by hand alone, by the hands aided by a lever, by a wheel, by coggs and cranks, or any other convenient mechanical power, and, if the strength of men be not sufficient, that of horses may be applied, and, even water, wind, and steam may be called in to our aid. This is however, by no means necessary. A strong man, after becoming accustomed to the exertion, will inject as much gas as will impart to the waters a degree of activity far surpassing any thing which they ever possess in nature. As this impregnation depends entirely on the pressure which is applied to the gas to force it into union with the water, it is obvious that the containing vessels must possess a degree of strength proportioned to the force which is to be applied. Glass is entirely improper, however thick, and apparently strong, because an explosion, which is no uncommon accident in these operations, would be attended with the most hazardous consequences. The vessels must therefore be made of wood or metal. Very strong casks of oak, made of the very best timber, and constructed in the most careful manner, are the most proper instruments, if we regard, primarily, the purity of the waters and the health of those who use them. The casks must be very strongly bound and guarded with iron hoops and strong iron bars in every direction; they must be furnished with an internal apparatus for agitation, or they must rotate on an axis to effect the same object. Their

strength must be such that they will not strain so as to produce cracks, or even the smallest aperture, for, absolute tightness is indispensable to success. In an apparatus of this kind, water may be combined with four or five times its bulk of carbonic acid gas, and it then dissolves iron with considerable rapidity, and the carbonates of lime and magnesia are also taken up by the excess of carbonic acid.

The containing vessel may be made of copper, tinned on the inside, and secured by being enclosed in a strong iron bound cask. This structure has the advantage of greater strength and tightness, and of being repaired with less difficulty than vessels made of wood. The only objection against it arises from the great tendency which copper has to become corroded by most chemical agents; the tin is a partial protection, but there is reason to fear that in the course of sometime, the tin will become so thin, as not to protect the copper, and thus a deleterious impregnation may get into the water.

2. Cold. With a given pressure more gas will be combined with water the colder it is kept during the operation. Therefore the containing vessels should, if possible, be surrounded with ice during the impregnation, or immersed in cold water. If the vessels have been suffered to lie in an ice-house and thus to become ice cold, it will greatly facilitate the combination.

3. Agitation. Most of the remarks under this head have been already anticipated. Agitation is necessary in order to bring the water and gas into complete mixture, and to mingle water that is more highly saturated with that which is less so, that thus there may be an equal distribution of principles, which, without agitation, it would take much longer to effect. At the end of the operation the water in the containing vessel exists under a prodigious pressure. In order to create fountains of mineral waters, nothing more is necessary than to connect a proper tube with the containing vessel, and let it pass into an upper room and terminate in any convenient or ornamental jet, furnished with a stop-cock. This apparatus should be made of materials that will not contaminate the water. On opening the stop-cocks, the water will, of course, be discharged with a velocity proportioned directly to the pressure in the containing vessel, and inversely to the distance which the water has to ascend. By means of a peculiar contrivance the impregnated water can be transferred from the containing vessel into bottles, still retaining nearly all the pressure which it had in the vessel; consequently when the bottles are opened, the fluid will fly or sparkle as the fermented liquors do. Glass bottles are not strong enough for this purpose, and the stone ware bottles of this country are not sufficiently firm in their texture to contain the impregnated water; the pressure forces it through the sides of the bottle upon which it appears like a dew. The bottles made for this purpose in London are entirely impervious.

IV. Hepatic Waters.

Waters of this description are so extremely offensive, on account of the fetid odour which attends them, that they are rarely demanded as an article of manufacture. On account of the action which they exert on most metallic substances it is proper that only clean glass vessels should be used in manufacturing them; a tub of wood *not painted*, may be used as a pneumatic cistern. In impregnating water with sulphuretted hydrogen it is not necessary to employ the powerful condensing machines which have been mentioned. Were there no objection to the use of metallic instruments, still, it would be unnecessary to condense into water a very large quantity of a kind of gas, of which the smallest portions can hardly be borne. Water impregnated with sulphuretted hydrogen as highly as soda water is with carbonic acid, would, when drawn, either from fountains or bottles, emit a most noxious and insupportable effluvium. To form an hepatic water, either a portion of one of the dry sulphurets of lime, soda, or potash, may be dissolved in water, when it will immediately acquire the hepatic odour; or, (a way that is probably better) sulphuretted hydrogen gas, derived from sulphuret of iron, and diluted sulphuric or muriatic acid may be passed into an inverted bottle containing water, in the manner that was mentioned for forming the acidulous waters. Agitation being used, a sulphureous water will be obtained, sufficiently strong for medical purposes. A sulphureous bath may be formed by passing a stream of sulphuretted hydrogen gas through a tub of water, taking care to agitate the water frequently. The gas that does not combine in its passage may be caught in an inverted jar, and poured from it into another, and back again, till the water is sufficiently impregnated. The hepatic waters frequently contain some of the ingredients of the preceding classes, and these may be added by very obvious means.

In manufacturing mineral waters of every description, and especially those of the three first classes, care should be taken to select a natural water, which is, in a common sense, pure, that is, free from any peculiarity of odour, taste, or colour.

Page 78. *Galvanism.*

Section I.

The splendid discoveries which have been recently made by the agency of this power, demand a share of attention proportioned to their novelty and importance. The galvanic electricity possesses a degree of energy in decomposing compound substances, which appears superior to that exerted by any other power, and has, all at once, thrown the most unexpected light on the nature of a number of bodies, and given the greatest celebrity to the name of Professor Davy. We have it, on the authority of this distinguished chemist, that all the experiments by which he made his discoveries, "may be repeated by means of a Voltaic battery, containing from 100 to 150 plates, of four or six inches," and most of his operations were performed, with a power of 100 plates of six inches. The plates are now almost universally made of zinc and copper, and a pair consists of one plate of zinc and one of copper, soldered together, or connected by a metallic arc, and the power will be in the compound ratio of the number and size of the plates.

The power of giving a shock, and of decomposing compound substances, is, however directly proportioned to the *number* of plates, if the surface of metal be given, while the power of burning the metals is dependent on the *size* of the plates. A battery of 50 plates whose diameter is 12 inches, is very powerful in burning the metals, but does not give a very strong shock, while, if the same plates be cut down into 200 of 6 inches diameter, the power of burning the metals will be found to be greatly reduced, while that of producing the shock and of decomposing compounds will be greatly increased. The plates are fixed in grooves at the distance of about half an inch made in boxes of well seasoned wood, and the partitions are made tight by cement; the cavities between the plates are filled with some saline or acid fluid; as, solutions of common salt, or alum, with the addition of a portion of one of the strong acids; the sulphuric, muriatic, or nitric; these acids themselves are the most active agents for exciting the galvanic energy, and, at present, it is common to employ a saline solution, because it is cheaper, while a portion of acid is added to increase its activity. A mixture of a solution of common salt and muriatic acid, or of a solution of alum and nitrous acid will answer very well, but, strong nitrous acid diluted with 30 or 40 parts of water is accounted the best. If muriatic acid be used, it should not be diluted with more than 20 or 25 parts of water.

The pile of Volta which was made by laying discs or plates of two different metals in pairs, one above another, interposing pieces of bibulous paper, felt, or cloth, moistened with some proper fluid, has now given way to the trough, and, in this, an alteration has been recently made, by dividing the box into a sufficient number of cavities, by partitions of wood or glass, cemented with rosin and wax; the plates, in pairs, are placed in these cavities and connected by leaden straps, while the cavities are filled as before. In every galvanic arrangement, the same order must be preserved; if the arrangement be zinc and then copper, it must be zinc-copper and not copper-zinc through the whole. When the battery is in action, the end of the trough which begins with zinc is always endued with the positive electricity, while the copper end is negative. Wires are commonly used to convey the power from one end of the battery to the other; any good conductor, and therefore any metallic substance will answer, but wires of platinum or of gold, as being but little liable to chemical change, are most commonly employed. It is not necessary that the apparatus should be insulated, but, insulation increases its power. The subject to be operated upon is placed between the points of the two wires, which, in general, must be brought pretty near to each other, as the galvanic electricity does not easily pass through a considerable distance in the air. The galvanic influence is now universally considered as the same with the electrical fluid, and, some of the most important laws of electricity are applied with success to the explanation of the phenomena of galvanism. The mode of excitement however is new, and appears to be capable of indefinite extension.

DAVY'S DISCOVERIES.

Miscellaneous Agencies of Galvanism.

The attention of philosophers had been, for several years, directed to the decompositions produced by galvanic electricity, and considerable difficulty attended the explanation of some of the phenomena. For instance, when the wires connected with the two ends of the battery are placed in a tube of water, the water is decomposed, and, if the wires are of platinum or gold, both gases are evolved in mixture and ascend to the top of the tube; if iron wires are used, then the oxygen combines with the iron, and the hydrogen alone is evolved. But, what appeared most extraordinary was, that this decomposition was equally produced when the wires were placed in different portions of the same compound, even in different vessels, provided these were connected by some conducting substance, so that, the elements were evolved at a distance from each other, and this distance was often considerable. To account for these singular results, it was suggested that the galvanic influence might have the power of conveying the elements of bodies to a distance, and that the positive pole might attract substances of one description, and the negative pole those of another. The experiments which had been before instituted on this subject, and which rendered the above conclusions extremely probable, have been greatly extended and diversified by Mr. Davy, who has fully illustrated and established these singular positions. A detailed account of his researches on this subject was communicated to the Royal Society of London, in the Bakerian lecture for November, 1806. (Nicholson's Journal, 8vo series, vol. XVIII. page 321.)

The general truth may be thus stated. Some bodies are attracted to the positive and some to the negative side of the galvanic series, and this attraction is exerted at considerable distances, and even when another body is interposed between the portions of the substance acted on by the wires, and, in this way, ponderable and often very heavy matter is conveyed through the interposed substance and the elements of a body are thus transported from one vessel and deposited in another.

Oxygen is uniformly attracted by the positive side, and is the only simple body which is thus attracted; those compounds in which it predominates, particularly the acids, are also attracted by the positive pole; while combustible bodies, " metals and the compounds in which they appear to have a predominating force, as, the alkalies, earths and metallic oxides, are attracted by the negative side. " Or, (Murray's system, 2d edition, vol. I. page 552) as the law is stated by Mr. Davy, galvanism and electricity being considered as identical, certain substances, oxygen and acids, are attracted by positively electrified metallic surfaces, and repelled by similar surfaces negatively electrified, while inflammable bodies, metals, metallic oxides, alkalies and earths are attracted by negatively electrified metallic surfaces, and repelled by those which are in a positive state." Thus, when water is decomposed by galvanism, the oxygen passes to the positive and the hydrogen to the negative side; when an alkaline salt is resolved into its constituent parts, the acid collects around the positive, and the alkali around the negative wire.

From among Mr. Davy's numerous and very satisfactory experiments, a few may be selected to illustrate these positions. His apparatus was simple. Generally two small vessels of glass, or, because of the liability of this substance to decomposition, of agate or gold, were employed; sometimes, for particular purposes, they were of sulphate of lime, sulphate of strontites, of Carrara marble, &c. Solutions of the compounds to be acted upon were placed in the vessels, and these were generally connected by a piece of moistened asbestos, or, amianthus laid over the lips of the vessels, so as to communicate with the fluid. When, for instance, boths cups contained sulphate of potash dissolved in water, and this was submitted to the action of 50 pairs of plates, of 6 inches square, at the end of four hours, the sulphuric acid was found all in one cup, and the potash in the other. The sulphate of soda, the nitrate of potash, the phosphate of soda and other salts gave similar results; their acids passing over to the positive, and the bases to the negative wire. If, instead of an acid solution, distilled water were placed in one cup, and a solution of a salt in water in the other, either the base or the acid was conveyed to the water according as the saline solution was connected with the positive or negative wire; if with the former, the acid was retained and the base repelled to the other pole, if with the latter, the base was retained and the acid repelled.

The containing vessels themselves, when they consisted of such substances as were liable to decomposition, yielded up their constituent parts, although, on account of their cohesion, more slowly than fluid bodies. Thus, cups of sulphate of lime, containing distilled water, when subjected to the action of a battery of 100 pairs of plates, of 6 inches, gave acid in the one and lime in the other; this change was perceptible in five minutes, and very obvious in an hour. Even metals are conveyed in this way, and insoluble earths, as silver from nitrate of silver, and magnesia from the sulphate of magnesia. (Murray, 2d edition, vol. I. page 554.)

Another fact still more singular, was discovered by Mr. Davy. He found that the chemical affinities of substances were so completely suspended by galvanism, that they could be made to pass through solutions of other bodies between which and themselves there was the strongest mutual attraction, without either affecting them, or being affected by them. Three vessels were employed, and, in one experiment, sulphate of potash was connected with the negative wire; ammonia was placed in the middle vessel, and pure water in the third connected with the positive wire; the result was, that the sulphuric acid was conveyed through the ammonia, and was found in the water. In the same manner, sulphuric acid was conveyed through solutions of lime, potash and soda; the nitric and muriatic acids were transmitted through concentrated alkaline menstrua; lime, magnesia, soda, potash and ammonia were sent through nitric, muriatic, and sulphuric acids without combining with them, and, both acid and alkaline bodies were conveyed through coloured vegetable infusions without affecting them.

The decompositions produced by galvanism are complete, the bodies evolved being found pure, and the wonderful effects which have been related appear to depend on powerful attractions and repulsions. It even appears that substances can be conveyed through solid matter, for which they have no evident affinity; as, when two tubes containing water are connected, the one with the positive, and the other with the negative wire, and the communication between them affected by a metallic rod, which may be even two or three feet long, oxygen will be discharged at the positive, and hydrogen at the negative wire, and there is no other way of accounting for the phenomenon, but by supposing that the oxygen or hydrogen has been conveyed along the metallic wire from the one tube to the other. So, Mr. Murray found that when the bend of a syphon was filled with mercury, and the legs contained a solution of a perfectly neutral alkaline salt, mixed with the infusion of cabbage, that, on passing the galvanic influence through the tube, the fluid which was connected with the positive wire speedily became red, and that with the negative green, thus, proving that the acid and alkali had been conveyed through the mercury; and, he justly remarks that no result can be more surprizing than this transfer of matter through another dense ponderable substance, incapable of forming any union with the conveyed matter.

These are some of the most important results detailed in the Bakerian lecture of 1806. They are very surprizing and have given rise to much speculation concerning the nature of the agency by which they are produced. There is no room in this short abstract for these discussions: we will only remark that whatever may be thought of Mr. Davy's suggestion that chemical affinity may be merely a modification of electrical energy, there can be no doubt that chemical phenomena are very greatly influenced by electrical powers, and we now hasten to relate effects of galvanic electricity still more astonishing than those which have been detailed.

Page 82. GALVANISM.

Section II.

Decomposition of Potash and Soda, &c.

The first attempts of Mr. Davy were made upon aqueous solutions of potash and soda, but the water alone was decomposed. He then kept the potash in perfect fusion by an ingenious contrivance; it was contained in a spoon of platinum which was, in the first instance, connected with the positive side of a battery of 100 of 6 inches, highly charged, and the connection from the negative side was made by means of a wire of platinum. A most intense light was exhibited, at the negative wire, and a column of flame arose from the point of contact. When the spoon was made negative, and the wire positive, a vivid and constant light appeared at its point, and aëriform globules which inflamed in the atmosphere rose through the potash.

A small piece of pure potash, slightly moistened by the air, so as to give it conducting power, was placed on an insulated disc of platinum, connected with the negative side of the battery of the power of 250 of 6 and 4, in a state of intense activity and a platinum wire, communicating with the positive side, was brought in contact with the upper surface of the alkali. The whole apparatus was in the open atmosphere.

There was a fusion of the potash at both surfaces—a violent effervescence at the upper, and at the lower, "small globules, having a high metallic lustre, and being precisely similar, in visible characters, to quicksilver, appeared, some of which burnt with explosion and bright flame, as soon as they were formed, and others remained and were merely tarnished and finally covered by a white film which formed on their surfaces."

These globules were the basis of the potash; they did not proceed from the platinum, for they appeared equally, whether copper, silver, gold, plumbago, or even charcoal, were employed for completing the circuit. The air had no agency in producing the globules, for, they were evolved when the alkali was placed in a vacuum.

" The substance was likewise produced from potash, fused by means of a lamp, in glass tubes, confined over mercury, and furnished with hermetically inserted platina wires, by which the electrical action was transmitted." But the glass was so rapidly decomposed by the substance that the operation could not be carried far.

" Soda, when acted upon in the same manner as potash, exhibited an analogous result ; but, the decomposition demanded a greater intensity of action in the batteries, or, the alkali was demanded to be in much thinner and smaller pieces. With the battery of 100 of 6 in full activity (says Mr. Davy) I obtained good results from pieces of potash, weighing from 40 to 70 grains, and of a thickness which made the distance of the electrified metallic surfaces nearly a quarter of an inch ; but, with a similar power, it was impossible to produce the effects of decomposition on pieces of soda of more than 15 or 20 grains in weight, and that only when the distance between the wires was about 1-8 or 1-10 of an inch."

" The substance produced from potash remained fluid at the temperature of the atmosphere, at the time of its production ; that from soda, which was fluid in the degree of heat of the alkali during its formation, became solid on cooling, and appeared to have the lustre of silver." When the power of 250 was used, with a very high charge for the decomposition of soda, the globules often burnt at the moment of their formation, and sometimes violently exploded, and separated into smaller globules, which flew with great velocity through the air in a state of vivid combustion, producing a beautiful effect of continued jets of fire."

THEORY OF THE PHENOMENA.

These decompositions agree perfectly with those which have been before described ; oxygen is evolved at the positive wire and the combustible with which it was united at the negative. When the solid potash or soda was decomposed in glass tubes, the new substances were always evolved at the negative wire, and the most delicate examination proved that the gas liberated at the positive wire was pure oxygen, and, unless more water was present than was necessary to give conducting power to the alkali, no gas whatever was given out at the negative wire. The synthetical proofs were equally satisfactory.

The bases of both alkalies, when exposed to the atmosphere, became tarnished and covered with a white crust, which immediately deliquesced ; water was decomposed, a farther oxydizement took place, more white matter was formed, and the whole became a saturated solution of fixed alkali. When the metallic globules were confined over mercury in oxygen gas or common air, an absorption took place, a crust of alkali instantly formed, and, for want of moisture the process stopped, the interior being defended from the action of the gas. " When the substances were strongly heated, confined in given portions of oxygen, a rapid combustion with a brilliant white flame was produced ; and the metallic globules were found converted into a white and solid mass which in the case of the substance from potash was found to be potash, and in that from soda, soda."

" Oxygen gas was absorbed in this operation, and nothing emitted which affected the purity of the residual air."

The alkalies produced were apparently dry, or at least contained no more moisture than might well be conceived to exist in the oxygen gas absorbed ; and their weights considerably exceeded those of the combustible matters consumed."

It appears then that potash and soda are composed of oxygen, and two peculiar substances resembling metals.

These combustible bases appear to follow the general law and to be repelled by the positive, and attracted by the negative wires, while the oxygen follows the contrary order; when they are brought together in their natural state they combine, and, if heat be applied, rapidly and with combustion.

PROPERTIES AND NATURE OF THE BASIS OF POTASH.

The basis of potash to which Mr. Davy gave the appropriate name of potassium, is so prone to combine with oxygen, that it was found almost impossible to preserve it, except under recently distilled naptha. In this, if air be excluded, it may be preserved, without considerable changing, for several days, and if covered with a film of naptha, it may be examined in the atmosphere.

These remarks are substantially applicable to the basis of soda, which Mr. Davy called sodium.

At 60° Fahrenheit, potassium appears in small globules, so similar to mercury that, when they are placed side by side, the difference cannot be detected by the eye. At 60°, however, it is only imperfectly fluid, at 70° it is more so, and, at 100°, perfectly so. At 50° it is soft and malleable, with the lustre of polished silver; at 32° brittle, and when broken, exhibits through a microscope, a crystallization in facets very white and splendid. It is vaporised a little below redness and is not altered by distillation. It conducts heat and electricity extremely well, and is burned by them both producing alkaline fumes. It floats in naptha, of the specific gravity .861, and did not sink in that which had been double distilled of the specific gravity, .77.

Its specific gravity at 62° is to that of water about as 6 to 10; it is therefore the lightest fluid known. When solid, it is a little heavier, but still swims in double distilled naptha.

CHEMICAL RELATIONS.

These are not less extraordinary than the physical ones. Its relations to oxygen have been already mentioned. It burns in this gas at the temperature which vaporizes it, and the heat and light are intense ; it combines with it at every temperature, and at about 400° is converted into a reddish oxide, mixed with potash ; and the whole becomes potash by being heated in fresh quantities of air, or by being exposed to water, and this oxide may be formed by fusing potash and its basis together.

Potassium burns spontaneously in oxy-muriatic acid gas, with a bright red light, and muriate of potash is formed.

Hydrogen gas heated in contact with potassium, dissolves it, and becomes spontaneously inflammable, but loses this property by standing, and deposits potassium again.

When potassium is brought into contact with a drop of water, *exposed to the atmosphere*, there is an instantaneous explosion, with a bright flame, and a solution of pure potash is the result.

In experiments of this kind, a white ring of smoke is often formed, similar to that evolved by phosphuretted hydrogen.

Water is rapidly decomposed by potassium, with much heat and noise, and *if the atmosphere be wholly excluded*, there is no inflammation, but pure hydrogen gas is evolved.

If potassium be placed upon ice, it instantly burns with a bright flame, and a deep hole is made in the ice, which is found to contain a solution of potash.

If it be placed upon moistened turmeric paper, it burns, moves rapidly around, and leaves a deep reddish brown stain.

It discovers and decomposes even the small quantities of water contained in alcohol and ether, and being insoluble in the latter, it forms in it, a turbid cloud of potash, while hydrogen is disengaged.

Thrown into solutions of the mineral acids, it inflames and burns on the surface, and, if confined beneath them it acts on the oxygen with the greatest intensity, and gases are extricated, such as might be expected from the nature of the acids. Potassium readily combines with phosphorus and sulphur, forming compounds similar to the metallic phosphurets and sulphurets.

The union with phosphorus can be effected by a slight pressure; that with sulphur requires that the sulphur should be fused; in both cases the air must be excluded or the materials will inflame. Much heat is produced during the combination, and all the phenomena are very similar to those which take place during the union of phosphorus and sulphur with the well known metals.

Potassium combines with mercury by mere contact, and the amalgam is fluid, soft, or brittle, according to the proportion of the metals. This amalgam decomposes water, hydrogen gas is evolved, potash is formed, and the mercury is disengaged; it deliquesces in the air, with similar phenomena; it dissolved all the metals to which it was applied, not excepting even iron and platinum.

Potassium, with the aid of heat, alloys with gold, silver, and copper, and the compound decomposes water, potash is formed, and the metals are separated unaltered. It forms an alloy with the fusible metal and renders it less fusible.

Potassium, when heated in the concrete oils (tallow, spermaceti, wax, &c.) acquires oxygen even from them, gas arises, the base is slowly converted into potash, and a soap is formed. It acquires oxygen even from naptha which has been exposed to the contact of the air. The fluid fixed oils are similarly, although more slowly affected, and the volatile oils are rapidly decomposed by potassium with the aid of heat. Melted camphor is blackened by it, decomposed, and a saponaceous compound formed. The metallic oxides are readily decomposed by potassium with the aid of heat, alkali is formed, and the metal liberated, and, if the potassium be in excess, it alloys with the metal*.

Potassium decomposes and corrodes, more or less, all the varieties of glass; green and flint glass are decomposed by a gentle heat; plate glass requires a red heat; these effects result from the action of potassium on the metallic oxides contained in glass, and also, from its action on the alkali of the glass which gives up a portion of its oxygen to the potassium, and thus an oxide of a brown colour is formed, which gradually passes to the state of alkali as it absorbs oxygen.

PROPERTIES AND NATURE OF THE BASE OF SODA.

Sodium is a solid at all common temperatures; it has the lustre and general appearance of silver; it is exceedingly malleable, and so soft, that when a globule of 1-10 or 1-12 of an inch in diameter is pressed upon by a platina blade, it is easily spread over a surface of 1-4th of an inch, and this property does not diminish when it is cooled down to† 32°. It conducts heat and electricity, and is inflamed by them both in a manner similar to potassium.

It swims in water, and, in oil of sassafras of the specific gravity of 1.096, water being 1. but it sinks in naptha of the gravity .861. Its specific gravity was estimated at .9348, water being 1.

Sodium has its cohesion impaired at 120°, runs fluid at about 180°, and may therefore be melted under boiling naptha. Its point of vaporization is not ascertained; it remains fixed in a state of ignition, at the point of fusion of plate glass.

CHEMICAL RELATIONS.

These are so similar to those of potassium that it will be necessary to do little more than point out the difference.

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* In Nicholoson's Journal, Vol. XXIV. page 92, is an account of some interesting experiments of Thenard, and Gay Sussac, upon the action of potassium on various salts and oxides, by which interesting results were exhibited.

Brown oxide of lead		Produced very vivid inflammation.
Sulphate of lead		
Nitrate of barytes		
Super-oxygenized muriates		
Red oxide of mercury		
Oxide of silver		
Oxide of antimony	At a maximum	
Oxide of tin		
Oxide of manganese		
Chromate of lead		Produced vivid inflammations.
Arseniate of cobalt		
Green and yellow tungstic acid		
Red oxide of lead		
Yellow oxide of lead		
Yellow and brown oxides of copper		
Yellow oxide of bismuth		

† Strong pressure will unite two pieces of sodium, so that they can be *welded* at a common temperature.

It combines with oxygen reproducing soda, but its attraction for oxygen appears to be less energetic than that of potassium; the process is slower, and the deliquescence of the alkali produced is not so rapid. The combination is accelerated by heat, but combustion in oxygen gas does not take place till near ignition; it then burns beautifully with a white flame and bright sparks, and, in common air, the flame is similar to that from burning charcoal, but much brighter. Hydrogen does not dissolve it. It burns in oxy-muriatic acid gas with bright red scintillations, and muriate of soda is the result. It decomposes water with violent effervescence, and a loud hissing noise; soda is formed, and hydrogen evolved, but there is no luminous appearance. In hot water the phenomena are more violent, and there are a few scintillations, owing to particles of sodium much heated and thrown into the air by the agitation. On moistened paper, or in contact with a small globule of water, as there is nothing to carry off the heat, the sodium usually inflames. The action on alcohol and ether and on the strong acids is the same that has been detailed with respect to potassium; with nitrous acid there is a vivid inflammation, but none with the muriatic and sulphuric, although, much heat is produced. In the action of sodium on the oils, and on naphta, on sulphur, and phosphorus, on mercury and several other metals, there is almost a perfect similarity with the action of potassium. The soaps are of a darker colour, and less soluble; the combination with sulphur, (effected as in the case of potassium in close vessels filled with the vapour of naptha) is attended with very vivid light, and much heat, and often explosion. The amalgam of mercury and sodium seems to form triple compounds with other metals; Mr. Davy thought that the mercury remained in combination with iron and platinum, after the sodium was alkalized, and separated by deliquescence. The amalgam forms a triple compound of a dark gray colour with sulphur.

PROPORTIONS OF OXYGEN AND BASE IN THE ALKALIES.

It would be inconsistent with the limits of this abstract to describe the ingenious processes, and to detail the difficulties connected with the experiments which Mr. Davy performed to ascertain these points. It will be sufficient to mention the principle of the operations and the result. A given weight of potassium or sodium was burnt in oxygen gas, and the quantity of gas absorbed, denoted the proportions of the compound. Water was decomposed by a given weight of these bases, or, (to render the operation more slow and manageable) by their amalgams, and the quantity of oxygen required for the saturation of the bases was estimated by that of the hydrogen gas disengaged.

Mr. Davy says; "comparing all the estimations, it will probably be a good approximation to the truth, to consider potash as composed of about 6 parts basis and 1 oxygen; and soda, as consisting of 7 basis and 2 oxygen." In 100 parts, potash may contain about 16, 6 of oxygen and soda about 28, 5.

CLASSIFICATION OF THE NEW BODIES.

It results from the preceding details that the bases of potash and soda "agree with metals in opacity, lustre, malleability, conducting powers as to heat and electricity, and in their qualities of chemical combination." Their low specific gravity is not a sufficient reason for making them a new class. The basis of soda is not much less than one sixth part of the weight of tellurium, and platinum is nearly four times as heavy as tellurium, so that the difference in specific gravity among the bodies that are now classed as metals is very great, and it is very possible that other bodies of a similar nature may yet be discovered, filling up the void, between the lightest of the metals and the bases of the fixed alkalis.* There can therefore be no sufficient objection to the admission of the new bodies into the class of metals, and the names potassium and sodium, as indicating the origin of the metals and as not being liable to be affected by any fluctuations of theory have been very properly given to them by their discoverer.

AMMONIA, &c.

Mr. Davy ignited charcoal by galvanic electricity in very pure ammoniacal gas, and carbonate of ammonia was formed; he passed ammoniacal gas over iron wire heated to redness in a tube of platinum ; the iron wire was oxydized and water formed ; similar results were obtained when ammoniacal gas was electerized over mercury, hydrogen and nitrogen were evolved as in the former experiments, and, from these and other similar considerations, Mr. Davy concluded that ammonia contains oxygen.

His words are ; "after these ideas, the oxygen in ammonia cannot well be estimated at less than 7 or 8 parts in the hundred ; and, it possibly exists in larger proportion, as the gases evolved may contain more water than the gas decomposed, which, of course, would increase their volume and their absolute weight."

"Oxygen then, may be considered as existing in, and as forming an element in all the true alkalies ; and the principle of acidity of the French nomenclature might now likewise be called the principle of alkalescence."

Mr. Davy concludes the Bakerian lecture of 1807, from which the preceding abstract is derived by suggesting some of the discoveries which might be anticipated as to the nature of the earths and the undecomposed acids, as well as other subjects, in consequence of the powerful agency of voltaic electricity, and the energetic affinities which the new discovered metals exert toward oxygen. He even mentions some experiments on the earths which countenance the opinion of their consisting of oxygen and metallic bases ; but, as these subjects must immediately be resumed, we will dismiss them for the present, and conclude this section with the following general conclusions expressed in Mr. Davy's words.

"In the electrical circuit, we have a regular series of powers of decomposition, from an intensity of action so feeble as scarcely to destroy the weakest affinity existing between the parts of a saline neutral compound, to one sufficiently energetic to separate elements in the strongest degree of union, in bodies undecomposable under other circumstances."

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* This idea has since been in part realized, by the discovery of metallic bases, in several of the earths, and they are heavier than sodium and potassium, and lighter than any of the before known metals.

"When the powers are feeble, acids and alkalies, and acids and metallic oxides, merely separate from each other; when they are increased to a certain degree, the common metallic oxides and the compound acids are decomposed; and by means still more exalted the alkalies yield their elements. And, as far as our knowledge of the composition of bodies extends, all substances attracted by positive electricity, are oxygen, or such as contain oxygen in excess; and all that are attracted by negative electricity are pure combustibles, or such as consist chiefly of combustible matter."

Page 85. Galvanism.

Section III.

Decomposition of the Earths.

The researches of Professor Davy were not so immediately successful in his galvanic operations upon the earths as were those upon the alkalies; but, the results were so satisfactory, that the compound nature of at least several of the earths is now sufficiently established.

When the same galvanic powers which had decomposed the alkalies, were applied by iron wires to barytes, strontites and lime, slightly moistened to give them conducting power, inflammable gas was copiously evolved, and, the earths at the negative wires "became dark coloured, and exhibited small points having a metallic lustre, which, when exposed to air, became white," as they did under water also, and gas was at the same time evolved, and a greenish powder seemed to separate. This result not being as plain as could be desired, potassium was heated in tubes of plate glass in contact with dry lime, barytes, strontites and magnesia, but, no good results were obtained in this way, as the glass would not bear the necessary heat.

When the voltaic power was passed through a mixture of dry potash in excess, and barytes, strontites, lime or magnesia, in fusion, "metallic substances were produced less fusible than potassium, which burnt the instant after they had formed, and, which by burning produced a mixture of potash and the earth employed."

Mixtures of the earths with various metallic oxides, as those of silver, mercury, tin, iron, and lead, were subjected to the galvanic action, and alloys or amalgams were obtained, containing a minute portion of the base of the earths, as appeared from the regeneration of the earths, when these products were exposed to the action of air or water.

When the power of a new battery of 500 pairs of plates of 6 inches was applied to mixtures of the earths and oxide of mercury, the heat generated was so great as to burn both the mercury and the basis of the earth, at the moment of its extrication.

In June 1808, Mr. Davy learned by a letter from Professor Berzelius of Stockholm, that he and Dr. Pontin had succeeded in decomposing barytes and lime in a mode which Mr. Davy immediately repeated, with perfect success.

"A globule of mercury, [negatively] electrified by the power of 500, weakly charged, was made to act upon a surface of slightly moistened barytes, fixed upon a plate of platina. The mercury gradually became less fluid, and after a few minutes was found covered with a white film of barytes; and when the amalgam was thrown into water, hydrogen was disengaged, the mercury remained free, and a solution of barytes was formed."

The result with lime was precisely analogous. From strontites a very rapid result was obtained; the process with magnesia was unsuccessful at first, but by keeping it constantly moist and continuing the operation for a longer time, "a combination of the basis with mercury was obtained, which slowly produced magnesia by absorption of oxygen from air, or by the action of water."

Even under naptha these amalgams became, after a length of time, covered with a white crust; in the air this change occurred in a few minutes; in water they were rapidly decomposed, barytes *most* rapidly; strontites next, and lime next; the amalgam of magnesia was but slowly changed, on account of the insolubility of magnesia, but, when sulphuric acid was added, hydrogen was evolved, and the change took place very rapidly, the mercury remaining free.

The amalgams were obtained from the salts of the earths also, viz. from the sulphate of magnesia, the muriate and sulphate of lime, the muriate of strontites and barytes, and nitrate of barytes. The sulphate of magnesia on account of its solubility afforded an amalgam even more readily than pure magnesia.

ATTEMPTS TO PROCURE THE METALS OF THE EARTHS; AND ON THEIR PROPERTIES.

The earths were slightly moistened, and mixed with one third of red oxide of mercury; the mixture was placed on a plate of platina; a cavity was made in the upper part of it to receive a globule of mercury, of from 50 to 60 grains in weight, the whole was covered with a film of naptha, and the plate was made positive, and the mercury negative, by a proper communication with the battery of 500."

In this manner larger quantities of the amalgams were obtained than in the other way.

These amalgams were distilled in tubes filled with the vapour of naptha and hermetically sealed. A part of the mercury rose pure by distillation, but, it was very difficult to separate the whole, for, when the temperature was raised sufficiently high, the tubes burst or were corroded. A very few successful results only, were obtained, in a multitude of trials, and, in no case was it absolutely certain that there was not a minute portion of mercury still in combination with the new metal.

The metal of barytes was white, like silver. It was fixed at all common temperatures, but became fluid at a heat below redness, and did not rise in vapour at a red heat, but acted violently upon the glass in which it was contained, producing a black mass, which seemed to contain barytes, and a fixed alkaline base, in the first degree of oxygenation.

It absorbed oxygen, and passed to the state of barytes. It acted violently on water, producing hydrogen, and returning to the condition of barytes. It sunk not only in water, but in sulphuric acid, although surrounded by bubbles of hydrogen, equal to two or three times its volume; whence it appeared probable that it was not less than four or five times as heavy as water. It was flattened by a considerable pressure.

"The metal from strontites sunk in sulphuric acid, and exhibited the same characters as that from barytes, except producing strontites by oxydation."

In distilling mercury off from the metal of lime, the tube broke, while warm, and the metal "which had the colour and lustre of silver, instantly took fire, and burnt with an intense white light, into quick lime."

The metal from magnesia, still combined with a little mercury was a white and brilliant solid. "It sunk rapidly in water, though surrounded by globules of gas producing magnesia, and quickly changed in air, becoming covered with a white crust, and falling into a white powder, which proved to be magnesia. It was ascertained by the use of balances that the metals of the earths acquired weight during their absorption of oxygen from the atmosphere, and that they were in the state of caustic earths after the operation, for they did not effervesce in acids, and produced much heat by the contact of water.

The alkaline earths then are compounds of oxygen and metallic bases, which bases, according to the general analogy, separate at the negative surface in the voltaic circuit, and the oxygen at the positive. Mr. Davy called these new metals barium, strontium, calcium, and magnium; barytum would however be better than barium, and magnesium than magnium, for the objection which Mr. Davy makes against this latter word, because Bergman applied it to manganese is not now of much importance, since that use of it is obsolete, and will probably not be revived.

ATTEMPTS TO DECOMPOSE ALUMINE, SILEX, ZIRCON, AND GLUCINE.

The Voltaic electrization of silex and alumine, carefully prepared and *pure* as they are commonly regarded, discovered that minute portions of the fixed alkalies used in their preparation still adhered to them although they could not be detected by the common chemical methods. In the same manner, Mr. Davy had found, in his earlier researches, that water, distilled with every precaution, still contained portions of saline and other matter sufficient to give decided indications after being subjected to galvanic action. He remarks with much propriety, "that the powers of electro-chemical analysis are continually demonstrating the imperfection of the common chemical methods of separating bodies from each other."

Mr. Davy's success with this class of earths was much less satisfactory than with the alkaline earths, but still he found good ground to conclude that they are compound. Passing over those attempts which, although ingenious, were unsuccessful, we will briefly advert to those results which gave indications of success.

Mixtures of silex of alumine, and of zircon respectively, were made with potash or soda in large excess and galvanized, while in fusion, in a platina crucible rendered positive, while a rod of platinum or a wire of iron completed the circuit on the negative side. There was vivid light and abundance of metallic globules rose through the fluid and inflamed in the air; metallic scales adhered to the negative conductor which appeared to be alloys of the bases of the earths with the metallic conductors; for, when plunged beneath water there was an effervescence, and on the addition of an acid, powders, which appeared to be the earths, were precipitated.

An amalgam of potassium, and one third mercury electrified in contact with silex slighty moistened, under naptha, decomposed water and when the alkali formed was neutralized by acetous acid, "a white matter, having all the appearance of silex precipitated."

The same methods produced a more distinct cloudiness from alumine and glucine. Zircon, in the same way, produced a fine white powder, soluble in sulphuric acid, and precipitated again from it by ammonia.

Upon a view of these facts Mr. Davy remarks, that "there seems very great reason to conclude, that alumine, zircon, glucine and silex are, like the alkaline earths, metallic oxides, for on no other supposition is it possible to explain the phenomena that have been detailed."

"The evidences of decomposition and composition are not however of the same strict nature as those that belong to the fixed alkalies, and alkaline earths; for it is possible, that in the experiments in which the silex, alumine and zircone appeared to separate during the oxidation of potassium and sodium, their bases might not have actually been in combination with them,but the earths themselves in union with the metals of the alkalies or in mere mechanical mixture."

Mr. Davy farther remarks, that out of an immense number of experiments, a very few only gave distinct indications of the production of any earthy matter, and the quantity was, in every instance, so small that it was impossible to decide on the species. Had Mr. Davy obtained perfectly satisfactory results, he would have proposed for these new metals the names silicium, alumium, zirconium and glucium.

METALLIC MATTER IN AMMONIA, &c.

In the communication from Professor Berzelius and Dr. Pontin, already mentioned, they informed Mr. Davy, that mercury, negatively electrified, in contact with solution of ammonia, gradually increases in volume, and when expanded to four or five times its former dimensions, becomes a soft solid.

"And that this substance is composed of the deoxygenated compound basis of ammonia and mercury, they think is proved; 1. By the reproduction of quicksilver and ammonia, with the absorption of oxygen, when it is exposed to air; and secondly, by its forming ammonia in water, while hydrogen is evolved, and the quicksilver gradually becomes free."

Mr. Davy repeated the experiment of the Swedish chemists, and obtained the same results, but, as it required a long time to produce the amalgam in this way, he made the trial in a different manner.

He made a cavity in a piece of muriate of ammonia; "into this a globule of mercury weighing about 50 grains was introduced. The muriate was slightly moistened to render it a conductor, and placed on a plate of platina made positive in the circuit of the larger battery. The quick-the decomposition and composition of nitrogen are proved; that oxygen is one of its elements, and he inquires "what is the other?"

Is the gas that appears to possess the properties of hydrogen a new species of inflammable aeriform substance?

Or has nitrogen a metallic basis which alloys with the iron and platina?

Or, is water alike the *ponderable* matter of nitrogen, hydrogen, and oxygen?

Or is nitrogen a compound of hydrogen with a larger portion of oxygen than exists in water?

From subsequent researches Mr. Davy concluded that nitrogen is a compound of oxygen and *hydrogen*, or that ammonia and water consist of the same kind of *ponderable* elementary matter, and, which ever conclusion may be adopted, it was believed that the decomposition of nitrogen is sufficiently established.

SULPHUR.

An opinion had been, for some time, supported, that sulphur contains hydrogen. In 1807, Mr. Davy, to ascertain this point, subjected sulphur to the action of galvanic electricity, and obtained from it sulphuretted hydrogen. In the summer of 1809, he repeated the experiment with every precaution which could ensure the purity of the sulphur and guard against the presence of water. The sulphur was contained in a glass tube, through which a platina wire was passed, hermetically sealed; the sulphur was melted by a spirit lamp, and the power of 500 double plates of 6 inches applied. "In this case the action was most intense, the heat strong and the light extremely brilliant; the sulphur soon entered into ebullition, elastic matter was formed in great quantities, much of which was permanent; and the sulphur from being of a pure yellow, became of a deep red brown tint."

The gas was sulphuretted hydrogen; the platina wires were considerably acted upon, and the sulphur, at its point of contact with them, had obtained the power of reddening moistened litmus paper. There seemed to be no limit to the generation of gas; in about two hours, a quantity had been evolved, which amounted to more than five times the volume of the sulphur employed. "Towards the end of the process the sulphur became extremely difficult of fusion and almost opaque, and when cooled and broken, was found of a dirty brown colour."

When sulphur and potassium combine, there is much heat and light, and an evolution of sulphuretted hydrogen gas, as Mr. Davy stated in a former communication. Mr. Davy concludes that, "the existence of hydrogen in sulphur is fully proved, and we have no right to consider a substance, which can be produced from it in such large quantities, merely an accidental ingredient."

In two experiments Mr. Davy heated potassium in very pure and dry sulphuretted hydrogen; "as soon as the potassium fused, white fumes were copiously emitted, and the potassium soon took fire and burnt with a most brilliant flame, yellow in the centre, and red towards the circumference."

Sulphur was liberated, and lined the upper part of the retort—there was a small diminution of gas—the residual gas was hydrogen still combined with a little sulphur—the solid residuum appeared to be sulphuret of potash externally, and sulphuret of potassium internally, and muriatic acid disengaged from it a little sulphuretted hydrogen.

"Both these experiments concur in proving the existence of a principle in sulphuretted hydrogen, capable of destroying partially the inflammability of potassium, and of producing upon it all the effects of oxygen."

Mr. Davy urges that the oxygen, existing in sulphuretted hydrogen, existed previously in the sulphur, because sulphuretted hydrogen can be formed by heating sulphur in pure hydrogen, under circumstances where oxygen could not be acquired from any foreign source; also, sulphur is precipitated from sulphuretted hydrogen by the electric spark, and the gas is not altered in volume; hence, he concludes, that the intense light and heat which attend the action between potassium and sulphur arise in part from the oxygen in the sulphur.

Mr. Davy concludes, "that sulphur, in its common state is a compound of small quantities of oxygen and hydrogen with a large quantity of a basis, that produces the acids of sulphur in combustion, and which, on account of its strong attractions for other bodies, it will probably be very difficult to obtain in its pure form."

PHOSPHORUS.

Phosphorus was subjected by Mr. Davy to the action of the Voltaic battery of 500, applied in the same manner as to sulphur. The light of the spark was at first a brilliant yellow, but, as the phosphorus changed to a deep red brown colour, the spark appeared orange. Gas was given out equal to four times the volume of the phosphorus, and it proved to be phosphuretted hydrogen. Potassium, heated in phosphuretted hydrogen did not inflame, but, underwent such a change as to induce Mr. Davy to conclude that phosphuretted hydrogen contains a minute portion of oxygen, and this opinion was strengthened by the action of potassium on phosphorus; they combine, with the production of the most vivid light and intense heat, and when three grains of phosphorus were combined with one grain of potassium, the compound generated less phosphuretted hydrogen, when acted upon by diluted muriatic acid than when the proportions were one grain of potassium and one of phosphorus, whence Mr. Davy concludes that more oxygen was transferred to the potassium by the larger quantity of phosphorus, and that thus its power of decomposing water was impaired.

He drew similar conclusions from similar experiments upon the union of sulphur and potassium, and found that "in no case was the quantity of gas equal in volume to the quantity of hydrogen, which would have been produced by the mere action of potassium on water." Respecting phosphorus, Mr. Davy concludes, that "though the quantity of hydrogen and oxygen in phosphorus may be exceedingly small; yet, they may be sufficient to give it peculiar characters," and he adds that "till the basis is obtained free, we shall have no knowledge of the pure phosphoric element.

PLUMBAGO. CHARCOAL. DIAMOND.

Plumbago acted upon in a Torricellian vacuum with the highest power of the battery of 500, did not emit any elastic matter, or suffer the smallest change, although the heat was such, as, in another experiment, instantly melted platina wire of 1-60 of an inch in diameter. .

Potassium was heated in contact with plumbago, in a plate glass tube; there was no ignition, but a slow combination seemed to take place, but, no such change was produced on the potassium as could authorize the conclusion that the plumbago contained oxygen, for, the potassium decomposed about as much water as an equal portion which was pure.

"Small pieces of charcoal from the willow that had been intensely ignited, were acted upon by Voltaic electricity in a Torricellian vacuum, every precaution being taken to exclude moisture; a flame seemed to issue from the charcoal of a most brilliant purple, and formed, as it were, a conducting chain of light of nearly an inch in length, at the same time that elastic matter was formed, some of which was permanent."

"When plumbago was used, after the first spark, which generally passed through a distance of about 1-8 of an inch, there was no continuation of light without a contact, or approach to the same distance."

The gas given out by half a grain of charcoal amounted to nearly half a cubical inch; "it was inflammable by the electric spark with oxygen gas, and four measures of it absorbed three measures of oxygen gas, and produced one measure and a half of carbonic acid."

The charcoal, at the point where it had been heated, had become harder, and had nearly the lustre of plumbago.

When potassium and charcoal were heated, although they produced a compound, there was no ignition, no gas was evolved, nor was there any proof of any oxygen being furnished to the potassium in the process.

Diamond, being a non-conductor, and infusible, could not be operated upon by Voltaic electricity.

When the diamond is heated in contact with potassium, it "soon blackens, and scales detach themselves from it, and these scales when examined in the magnifier, are gray externally, and of the colour of plumbago internally, as if they consisted of plumbago covered by the gray oxide of potassium."

In another experiment, the potassium became black, and the diamond fragments were covered with a grayish crust, which, when separated by washing, appeared as a fine powder of a dense black colour, and, when it was burnt by the Voltaic spark, produced carbonic acid.

Mr. Davy says: "These general results seem to show, that in plumbago the carbonaceous element exists merely in combination with iron, and in a form which may be regarded as approaching to that of a metal in its nature, being conducting in a high degree, opaque, and possessing considerable lustre."

"Charcoal appears to contain a minute quantity of hydrogen in combination. Possibly, likewise, the alkalies and earths produced during its combustion exist in it not fully combined with oxygen; and according to these ideas, it is a very compounded substance, though, in the main, it consists of the pure carbonaceous element."

"The experiments on the diamond render it extremely likely that it contains oxygen; but the quantity must be exceedingly minute, though probably sufficient to render the compound non-conducting; and, if the carbonaceous element in charcoal and the diamond be considered as united to still less foreign matter in quantity, than in plumbago, which contains about 1-20 of iron, the results of their combustion as examined independently of hygrometrical tests, will not differ perceptibly."

"Whoever considers the difference between iron and steel, in which there does not exist more than 1-200 of plumbago, or the difference between the amalgam of ammonium and mercury, in which the quantity of new matter is not more than 1-1000, or that between the metals and their sub-oxides, some of which contain less than 1-10 of oxygen will not be disposed to question the principle, that minute differences in chemical composition, may produce great differences in external and physical characters."

Page 183. *Decomposition and Recomposition of Boracic Acid.*

In the lecture on the decomposition of the fixed alkalies, Mr. Davy mentioned his having obtained a dark coloured combustible substance at the negative pole, during the action of Voltaic electricity on Boracic acid. In subsequent researches, in which he used the power of 500, "an olive brown matter immediately began to form on the negative surface, which gradually increased in thickness, and, at last, appeared almost black." An acid was produced when it was burnt.

But the most successful results were produced in a different way. "When equal weights of potassium and boracic acid were heated together in a green glass tube, filled with hydrogen, there was a most intense ignition, before the temperature was nearly raised to the red heat; the potassium entered into vivid inflammation, where it was in contact with the boracic acid, and when the boracic acid had been heated to whiteness before the operation, only a very little gas, (hydrogen) was evolved. When more than 12 or 14 grains of each substance were employed, the glass tube always melted from the intensity of the action. It was found by various trials, that 8 grains of boracic acid were competent to destroy entirely the inflammability of 20 grains of potassium.

Tubes of iron, brass and copper were used for obtaining larger quantities of the base of boracic acid; they were furnished with stop-cocks and filled with hydrogen gas. The properties of the specimens described, are taken from those procured in the brass tubes. "It appeared as a pulverulent mass of the darkest shades of olive. It is perfectly opaque. It is very friable, and its powder does not scratch glass. It is a non-conductor of electricity."

Heated in the air it burns, below the boiling point of olive oil, with a red light, and scintillations like charcoal.

It is not volatilized by a white heat; it becomes a little darker, and so much more dense as to sink rapidly in sulphuric acid, in which it did not sink before. In a retort filled with oxygen gas, and heated by a spirit lamp, it burns brilliantly, a sublimate of boracic acid rises; another portion of acid forms a vitreous coating on the mass; and after it has been washed off, the residuum is perfectly black, and, with the aid of a higher temperature, burns and produces more boracic acid.

In oxy-muriatic acid gas, it burns spontaneously, with a brilliant white light, a white substance coats the interior of the vessel, a film of boracic acid covers the residuum which is black, and does not inflame in a fresh portion of gas, without the application of a gentle heat, and boracic acid is the result. The peculiar substance did not dissolve in hydrogen and nitrogen, but became darker.

In nitric acid, nitrous gas was disengaged; when the nitric acid was heated, the action was more rapid, the substance disappeared, and boracic acid was found in the fluid.

In hot sulphuric acid there was an effervescence; a solution, and by the addition of potash a black precipitate appeared.

Muriatic acid heated in contact with it, acquired a green colour, but there was no vividness of action, or considerable solution.

With acetic acid there was no action.

With the fixed alkalies it gave pale olive coloured compounds, from which muriatic acid threw down dark precipitates.

By long fusion with sulphur, it was dissolved, and the sulphur acquired an olive tint.

Between it and phosphorus there was scarcely any action, only the phosphorus acquired a tint of pale green.

There was no combination with mercury, even when heat was applied.

Mr. Davy concludes that the substance obtained from boracic acid is different from any other known species of matter, and that the boracic acid, on account of the large quantity of potassium which is required to decompose it, must contain a considerable proportion of oxygen.

From the action of potassium on a given quantity of boracic acid, and from the quantity of oxygen which is known to be necessary to saturate potassium, Mr. Davy concluded, in one experiment, that boracic acid must consist of about one part of the peculiar inflammable substance to nearly two parts of oxygen.

From another experiment, in which the peculiar substance was burnt in oxygen gas, the proportions inferred, were one of the inflammable matter, to about 1,8 of oxygen. These conclusions were however considered as approximations only, and not as perfectly correct.

Mr. Davy is inclined to think that the peculiar substance, which has been described, is not simple; this he infers from "its being non-conducting, its change of colour by being heated in hydrogen gas, and its power of combining with the alkalies; for these properties belong in general to primary compounds, that are known to contain oxygen."

When heated with potassium, there was a gray metallic mass formed, which decomposed water, and there was no appearance which would justify the conclusion, that oxygen had been added to the potassium.

In another experiment, the olive coloured substance with 1-4 or 1-5 of potassium was heated to whiteness in a platina tube filled with hydrogen. A compound was produced of a dense black colour, and with a lustre almost equal to that of plumbago. It conducted electricity, produced a slight effervescence with water; a solid matter separated, which appeared dark olive, and the water became slightly alkaline. "Some of the olive inflammable matter, with a little potassium, was heated to whiteness, covered with iron filings; a dark metalline mass was formed, which conducted electricity, and which produced a very slight effervescence in water, and gave, by solution in nitric acid, oxide of iron and boracic acid."

"The substance, (says Mr. Davy,) which enters into alloy with potassium, and with iron, I am inclined to consider as the true basis of boracic acid."

"In the olive coloured matter this basis seems to exist in union with a little oxygen, and when the olive coloured substance is dried at common temperatures, it likewise contains water."

"In the black non-conducting matter, produced in the combustion of the olive coloured substance, the basis is evidently combined with much more oxygen; and in its full state of oxygenation, it constitutes boracic acid."

"From the colour of the oxides, and their solubility in alkalies, from their general powers of combination, and from the conducting nature and lustre of the matter produced by the action of a small quantity of potassium upon the olive coloured substance, and from all analogy, there is strong reason to consider the boracic basis as metallic in its nature, and I venture to propose for it the name of *boracium.*"

Page 184. *Decomposition and Recomposition of Fluoric Acid.*

In Mr. Davy's communication on the decomposition of the earths, he mentioned that potassium burns in fluoric acid gas.

On a more particular examination of this subject, he informs us that, when potassium is placed in contact with fluoric acid gas that has been procured in contact with glass, white fumes are perceived, the metal loses its splendour, and becomes covered with a grayish crust; the application of a gentle heat renews the fumes, but they cease after a while, and the volume of the gas is found to be increased by the addition of a little hydrogen. No new fumes are produced by the second application of a low heat; but when the temperature is raised nearly to the point of sublimation of potassium, the metal rises through the crust, becomes first of a copper colour and then of a bluish black, and soon after inflames and burns with a most brilliant light.

Fluoric acid gas is absorbed or destroyed, and a sublimate, in some parts chocolate, and in others yellow, is found round the sides and at the top of the retort; a small portion of hydrogen gas remains, varying according to the quantity of water which has been present in the fluoric gas.

When 18 or 20 grains were heated in contact with 20 or 30 cubical inches of fluoric acid gas, the retort was melted by the heat produced in the action. In one experiment, 10 1-2 grains of potassium were heated in 19 cubical inches of gas, about 14 inches disappeared, and 2 1-4 of hydrogen were evolved. There was very little sublimate; but the whole of the bottom of the retort was covered with a brown crust; a magnifier exhibited a blackish substance, a white and apparently saline substance, and one having different shades of brown and fawn colour. The mass did not conduct electricity; it effervesced violently in water, and emitted an inflammable gas having some resemblance in smell to phosphuretted hydrogen.

When heated in air, it burnt slowly, and became a white saline mass.

It burnt also when heated in oxygen gas, but slowly, and required a heat approaching redness; oxygen was absorbed, and the light given out in the combustion, was similar to that emitted by liver of sulphur when burning.

When the water, which had acted upon a portion of it, was examined, chocolate coloured particles were found floating in it, and the fluid was found to contain fluate of potash, and potash.

The solid matter separated by the filter, was heated nearly to redness in a glass retort, it burnt and became white, and oxygen was absorbed. " The remainder possessed the properties of the substance formed from fluoric acid gas, holding siliceous earth in solution by the action of water.

The portion of solid matter separable from the water, had been so small, that Mr. Davy was " not able to gain fully decided evidence, that the inflammable part of it is the pure basis of the fluoric acid; but, with respect to the decomposition of this body by potassium, and the existence of its basis at least combined with a smaller proportion of oxygen gas, it is scarcely possible to entertain a doubt."

This decomposition is analogous to that of the acids of sulphur and phosphorus by potassium, where the pure bases are not evolved, but new compounds. Silex was always obtained in the combustion of the residuum, after lixiviation, and the idea that it might be a compound of the silicious and fluoric base was countenanced by the fact, that, although no silex was obtained by boiling the mass in concentrated fluoric acid, still silex was always formed when the substance was burnt.

Fluoric acid, pure from silex, that is, obtained by the action of boracic acid in an iron tube, at a white heat, on fluate of lime, was made to pass over potassium placed in that part of the tube, where it was heated only to a dull redness. The result " was in some parts black, and in others of a dark brown. It did not effervesce with water; and when lixiviated, afforded a dark brown combustible mass, which did not conduct electricity, and which, when burnt in oxygen gas, afforded boracic and fluoric acid. It dissolved with violent effervescence in nitric acid; but did not inflame spontaneously in oxy-muriatic acid gas."

Mr. Davy is inclined to think that this substance is a compound of the olive coloured oxide of boracium, and an oxide of the fluoric basis.

An attempt was made to decompose the liquid concentrated fluoric acid, by the Voltaic electricity from 250 plates of 6 inches, but, only a small portion of a dark brown matter, which produced an acid by combustion, was evolved at the negative pole; both oxygen and hydrogen were also evolved.

Attempts were made to decompose the fluoric acid by heating in it the olive coloured substance obtained from the boracic acid, and by heating potassium with fluor spar, but no satisfactory results were obtained.

Page 158. *Muriatic Acid.*

On this subject Mr. Davy has made a greater number of researches than upon any other, but they have not been attended with the desired success. We shall not attempt therefore to follow the indefatigable professor in his interesting, although, as yet, fruitless labours on this subject. A few facts only will be stated.—In all the attempts that have been made (and they have been numerous) to decompose liquid muriatic acid either by common or galvanic electricity, the water alone is decomposed, and this is the case also with the gas itself, which Mr. Davy concludes to hold suspended one third of its weight of water.

Strong hopes were entertained, that potassium would decompose the acid, but these have not been realized; for, "when potassium is introduced into muriatic acid gas, rendered as dry as possible, it immediately becomes covered with a white crust, it heats spontaneously, and, by the assistance of a lamp acquires in some parts the temperature of ignition, but does not inflame. When the potassium and the gas are in proper proportions, they both entirely disappear; a white salt is formed, and a quantity of pure hydrogen evolved, which equals about one third of the original volume of the gas."

Mr. Davy took care to ascertain, that, in these cases, none of the muriatic acid was decomposed, for it was capable of producing as great a quantity of muriate of silver, as another equal portion of muriatic acid, which had not been exposed to the action of potassium.

Mr. Davy attempted in various ways to obtain dry muriatic acid, but he could not be assured in any instance that he obtained it pure.

But while exposing potassium to heat in contact with fluids that had distilled over during the action of phosphorus on corrosive sublimate, and during the action of sulphur on oxy-muriatic acid gas, he met with such surprising and violent inflammations and explosions, that the attention of the chemist cannot fail to be directed to these singular facts, in which, as Mr. Davy conjectures, "the muriatic cannot be entirely passive;" "and it does not (he adds) seem unfair to infer that the transfer of its oxygen, and the production of a novel substance are connected with such effects; and that the highly inflammable nature of these new compounds, partly depends upon this circumstance."

The subject is still under investigation, and we may hope for a happy result.

Mr. Davy concludes the last of his communications that has been received in this country,* (Nicholson's Journal, 8vo. vol. 24. p. 105.) with these words.

"The facts advanced in this lecture afford no new arguments in favour of an idea, to which I referred in my last communication to the society, that of hydrogen being a common principle in all inflammable bodies; and except in instances which are still under investigation, and concerning which, no precise conclusions can as yet be drawn, the generalization of Lavoisier happily applies to the explanation of all the new phenomena."

* Feb. 1, 1810.

"In proportion as progress is made towards the knowledge of pure combustible bases, so in proportion is the number of metallic substances increased; and it is probable, that sulphur and phosphorus, could they be perfectly deprived of oxygen, would belong to this class of bodies. Possibly their pure elementary matter may be procured by distillation, at a high heat, from metallic alloys, in which they have been acted upon by sodium and potassium. I hope soon to try this experiment.

"As our inquiries at present stand, the great general divisions of natural bodies is into matter, which is, or may be supposed to be, metallic, and oxygen; but, till the problem concerning the nature of nitrogen is fully solved, all systematic arrangements made upon this idea must be regarded as premature."

FRENCH EXPERIMENTS.

Boracic Acid.

Mr. Davy is, without doubt, the author of the first successful researches on the composition of boracic acid, but the credit of this discovery is due also to Gay Lussac and Thenard of Paris, who used the same means that Mr. Davy last employed, viz. the action of potassium. The result of their researches corresponds extremely well with Mr. Davy's, and the conclusions which they have drawn are almost exactly the same. They however give to the peculiar substance the name *bore*, and think that it ought to be ranked with phosphorus, carbon and sulphur.

FLUORIC ACID.

Gay Lussac and Thenard have also decomposed the fluoric acid, by the same means that Mr. Davy last employed. Their results were very similar to his. The combustible base which they obtained, burnt however more vividly than it did in Mr. Davy's experiments. They say; "when thrown into a silver crucible at a cherry red heat, it burns vividly and disengages a little acid gas"—in oxygen "the inflammation is more vivid than in common air, a great quantity of oxygen is absorbed, and the gas that remains after the combustion, is nothing but pure oxygen, with the addition of a little fluoric acid."

There is no evidence that in these experiments either the French borrowed from the English, or the English from the French; but their *independent* researches are to be regarded as mutual confirmations.

Gay Lussac and Thenard, hoping to obtain a very dry and pure fluoric acid, heated fluate of lime and glacial boracic acid together in an iron tube. They obtained an acid gas of which water absorbs more than 2000 times its bulk, and the fluid is limpid, fuming, and exceedingly caustic; heat will expel only 1-5 of this acid; it then resembles sulphuric acid; it is equally caustic; acts with equal energy on vegetable substances, converting them into charcoal. Yet this acid had no action on glass, and, on examination, it was discovered to be a compound of the fluoric and boracic acids; this compound is however possessed of such very energetic properties, that it deserves particular attention.

CHEMICAL METHODS OF DECOMPOSING POTASH.

Soon after the happy discovery of the galvanic decomposition of the alkalies by Mr. Davy, Gay Lussac and Thenard effected the same object in another way.

"Clean iron filings or iron shavings are placed in a gun-barrel, bent so that the iron shall be in the curvature, and the barrel is placed across a furnace. With one extremity of it a tube with a stopper is connected, containing solid potash. When the iron filings in the barrel are brought to a white heat, the alkali in the tube which has been previously kept cold by a freezing mixture, is melted by applying heat to it by a portable furnace, and it is allowed to run through a small aperture upon the iron filings. It suffers decomposition, the iron attracts its oxygen, and the inflammable base is sublimed to the other extremity of the tube, which is kept cold, so as to condense it; a tube of safety, containing a little mercury, being connected with the extremity, to allow of the disengagement of any aerial matter, and at the same time exclude the air. Hydrogen gas is disengaged during the process, which appears to be derived from the decomposition of water, contained in the alkali, and the result is most successful, when the alkali is in its dryest state. The base of the alkali is obtained in the form of brilliant laminæ, adhering to the sides of the gun-barrel; there is also found in the curvature, where the filings were contained, an alloy of it with iron." (Murray 2d Edition, vol. II. p. 185.)

Mr. Davy performed the experiment in the following manner. "An ounce of potash was kept in ignition for some time in an iron tube, ground into a gun-barrel in which one ounce and a half of iron turnings were ignited to whiteness; a communication was opened by withdrawing a wire which closed the tube containing the potash, between that alkali and the metal."

Half a cubic foot of hydrogen gas was disengaged, and "in the tube was found two products, one in the quantity of a few grains containing potassium combined with a small quantity of iron, which had sublimed in the operation, and the other a fixed white metallic substance, which consisted of an alloy of iron and potassium."

The potassium obtained in this manner, is found to be nearly pure and sufficiently so for every useful purpose, and the expense and trouble bear no comparison to what is incurred in the other process. Mr. Davy informs us also, that, "potash or pearlash is easily decomposed by the combined attractions of charcoal and iron; but, it is not decomposable by charcoal, or, when perfectly dry, by iron alone. Two combustible bodies seem to be required by their combined affinities for the effect; thus in the experiment with the gun-barrel, iron and hydrogen are concerned."

Mr. Davy considers Homberg's pyorphorus as a triple compound of potassium, sulphur and charcoal, for, he supposes the potash to be decomposed by two affinities. He says, the substance is perfectly imitated by heating together 10 parts of charcoal, 2 of potassium and 1 of sulphur.

Curaudau, a French chemist has given a new process, by which potash may be decomposed in an iron tube, or earthen retort.

"*Process the first.*"

"Mix intimately four parts of animal charcoal, well powdered with three of carbonate of soda, dried on the fire without having been fused; and mix the whole with a sufficient quantity of linseed oil, but, not so as to form a paste."

"*Process the second.*"

"Take two parts of flour and mix them intimately with one part of carbonate of soda, prepared as in the preceding process, and add to this mixture as much linseed oil as it will bear without ceasing to be pulverulent." Begin by heating gradually till the heat is about that of melting iron; then the metal is disengaged in a copious vapour.

The metal is collected by plunging into the vacuum of the iron tube a clean iron rod; it must be taken out in 4 or 5 seconds, when it will be found covered with metal, to remove which, plunge it instantly into a vessel of essence of turpentine, standing in water to keep it cool.

Much manual dexterity is necessary in the whole operation. If the heat be suffered to rise too high, the apparatus will melt; if it is too low, no metal will be formed, but alkali undecomposed will sublime.

Remark. This discovery of Curaudau is interesting, but, it would seem as if the process might be improved by having a tube of sufficient length to allow of its being kept cool so as to condense the metal; or, if it be necessary to introduce the metal into essence of turpentine, this might be done by causing a curved tube to pass into this fluid, where the metal might be at once deposited.

Page 102. *Respiration.*

Messrs. Allen and Pepys of London, have recently performed a very interesting series of experiments on human respiration. (Nicholson's Journal, Vol. XXII. p. 180.)

The air was inspired from a water gazometer, and expired into mercurial gazometers, and portions of every specimen were examined; the most important conclusions were, as follows:

1. The quantity of carbonic acid gas emitted, is exactly equal, bulk for bulk, to the oxygen consumed, and therefore there is no reason to conjecture, that any water is formed by an union of oxygen and hydrogen in the lungs.

2. Atmospheric air once entering the lungs, returns charged with from 8 to 8.5 per cent. of carbonic acid gas, and it acquires only 10 per cent. when the contacts are repeated almost as frequently as possible; rapidity of respiration does not increase the *proportion*, although it augments the *absolute quantity* of carbonic acid in a given time; but the proportions of this gas in the first and last portions of a deep inspiration, differ as widely as from 3.5 to 9.5 per cent.

3. A middle sized man, about 38 years of age, gave off 302 cubic inches of this gas, from his lungs, in 11 minutes, and, taking this for a ratio, the total quantity for 24 hours would be 39534 cubic inches, weighing 18683

grains; the carbon in which is 5363 grains, or, rather more than 11 oz. troy. The oxygen consumed in the same time will be equal in volume to the carbonic acid gas.

4. When respiration is attended with distressing circumstances, there is reason to conclude that a portion of oxygen is absorbed; as the oxygen decreases in quantity, perception gradually ceases, and we may suppose, that life would be completely extinguished on the total abstraction of oxygen.

5. A larger proportion of carbonic acid gas is formed from oxygen than from atmospheric air.

6. An easy natural inspiration (in the subject of Messrs. Allen and Pepy's experiment, who made about 19 inspirations in a minute,) was from 16 to 17 cubic inches.

7. No hydrogen, or any other gas [other than oxygen, carbonic acid, and azote] appears to be evolved during the process of respiration.

8. The bulk of the air thrown out from the lungs is very nearly the same with that taken in, and, any *apparent* difference appears to depend on the difficulty of bringing the lungs to exactly the same state at the end as at the commencement of the experiment, and the quanity of air remaining in the lungs is always considerable.

METEORIC STONES.

The falling of stones from the atmosphere, is now universally admitted, not only by philosophical men, but, such a mass of evidence has been accumulated on the subject, that both the knowledge and belief of these events have become general.

The phenomenon is usually connected with the appearance of luminous meteors, or fire balls. Their apparent diameter is sometimes as large as the moon*; "from the main body, frequently extends a flame or train. Streams and sparkles of fire seem to shoot out on every side. Just before their disappearance, there is a violent explosion, by which pieces often appear to be detached, and thrown to the ground."

" When the stones have fallen in the *day* time, the meteor has not always been observed; probably, because its light was not sufficiently strong, to draw the attention of persons abroad, to that part of the heavens, in which it was moving. But, even in this case, the same kind of *report* has been heard, as that which usually follows the explosion of a meteor. In many instances, the luminous body has been seen to come forward to the zenith, and apparently to burst; and, immediately after, the stones have fallen with a whizzing noise, to the ground."

Meteors of this kind are seen, in some parts of the world, almost every year, and the same meteor is often seen over a great extent of country; in some instances, a hundred miles in breadth, and five hundred in length. (Day's view).

Their perpendicular altitude during the time in which they are visible is calculated to be from 20 to 100 miles; and their diameter is, in some cases, estimated to be at least half a mile.

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* See Professor Day's view of theories on this subject. (Memoirs of Connecticut Academy, Vol. I. Part I. page 164.

Their velocity cannot be less than 300 miles in a minute.

It has not been ascertained that these meteors do, in every instance, project stones to the ground ; but, stones have been observed to descend in so many instances immediately after the explosion of meteors, as sufficiently to establish the point that the stones do proceed from the meteor, and, it may be presumed that, in numerous instances, they have fallen into the water, or other inaccessible places, or been effectually concealed, by being buried in the ground, in consequence of the violence of their descent.

The number of well authenticated instances in which stones have fallen from the atmosphere is now so great, that, instead of attempting to enumerate them all, we shall make a selection of the most important only.

There have been traditionary and historical accounts of the falling of bodies from the heavens, from very remote antiquity. Sometimes they were regarded as objects of idolatrous worship ; such was the *το διοπετους* (or that which fell down from Jupiter) of the Ephesians.

Livy mentions a shower of stones at Rome, under Tullus Hostilius, and a similar event is recorded to have happened there under the Consuls C. Martius and M. Torquatus. Pliny mentions a shower of iron in Lucania, the year before the defeat of Crassus, and that a very large stone fell in Thrace, in the 78th Olympiad, and three large stones are asserted to have fallen in the same country, about 452 years before Christ*. These and other similar assertions in ancient history were uniformly regarded, by the moderns, as instances of falsehood, or of excessive credulity and superstition ; but they are now treated with more respect, and little doubt remains in the minds of men of science, that stones have fallen in every age of the world.

On the 7th of June, 1492, a large stone, weighing 260 pounds, fell at Ensisheim, in Upper Alsace, in France ; it was preserved, till within a few years past, in a church, and was regarded as a sacred object. It fell in a storm, when the heavens appeared to be on fire, and, after a loud report like a clap of thunder.

About 120 stones, among which was one of 120 and another of 60 pounds weight, fell near Padua, in the year 1510.

In 1627, the great astronomer Gassendi saw a burning stone of 59 pounds, fall on Mount Vaiser, near the city of Nice, in France.

In 1706, a stone of 72 pounds fell, near Sarissa, in Macedonia.

In 1750, a stony mass fell at Niort, in Normandy.

In July, 1753, there was a shower of stones at Plann, near Tabor, in Bohemia ; and, in September, two stones, weighing 20 pounds, fell at Siponas, in Bresse ; and still another instance occurred in the same year, in the Eichstadt country, in Germany. A labourer at a brick kiln, when the ground was covered with snow, saw a body fall immediately after a violent report like thunder. He ran to the spot but the stone still retained so much heat, that it could not be handled. It was about six inches in diameter.

In 1762, two stones, of 200 and 300 pounds, fell near Verona.

"On the 13th of September, 1768, a tempestuous cloud was seen near the castle of Sucè, in Main. From this was heard an explosion like thun-

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* Many of the facts stated in this abstract are taken from a table drawn up by Mr Izarn, and which may be found in the Phil. Mag. XV. 182, and Thomson's Chemistry, second edition, Vol. III. page 419.

der; but, without the appearance of lightning, and, directly after, a remarkable whizzing noise in the air. A number of travellers looking up, saw an opake body descend in a curve line, and fall at a little distance from them. They all ran to the place, and found a kind of stone half buried in the ground, and too hot to be touched." (Professor Day's Discourse.)

In the same year a stone fell at Aire, in Artois, and another at Le Cotentin.

A shower of stones fell at Barboutan, near Roquefort, in July 1789.

July 24, 1790, there was an extensive shower of stones in the environs of Agen*.

June 16, 1794, about 7 o'clock, P. M. at Sienna, in Italy, a tremendous cloud came from the north, sending forth sparks like a rocket, burning, and smoking like a furnace, producing violent explosions, and casting down stones to the ground. The cloud was very high. The stones, which were about twelve in number, fell at the feet of several persons.

December 13, 1795, near the Wold Cottage, in Yorkshire, England, unusual noises, like distant reports of pistols or guns, and, also a *whizzing* were heard in the air; there was no thunder or lightning. A labourer saw a body descend and strike the ground; several persons went immediately to the spot, and found an extraordinary stone, weighing 56 pounds, buried 21 inches in the earth. It was warm, smoked, and smelt strongly of sulphur.

February 19, 1796, a stone of 10 pounds fell in Portugal.

March 12, 1798, one of 20 pounds fell at Sales, near Ville Franche, and, on the 17th of the same month and year, another, of the same weight, at Salé, Department of the Rhone.

December 19, (same year,) about 8 o'clock, in a clear serene evening, a large fire ball was seen at Benares, in Bengal; it was attended by a loud noise like thunder, or a discharge of musquetry, and a shower of stones fell in a neighbouring field, and buried themselves about 6 inches deep.

April 26, 1802, about 1 o'clock, P. M. near L'Aigle, in Normandy, a very brilliant fiery globe was seen to move very rapidly through the atmosphere. Immediately after, a violent explosion, which lasted five or six minutes, was heard at the distance of 30 leagues, in every direction from L'Aigle. The sky was serene and calm, and there were only a few light clouds. A shower of stones fell in various parts of a district 7 miles in length, and 2 or 3 in breadth; the largest stone weighed 17 pounds, and the whole number was thought to be two or three thousand. One of them (presented by Col. Gibbs,) is preserved in the cabinet of Yale College.

One of the most remarkable occurrences of the kind on record happened at Weston, in Connecticut, on the 14th of December, 1807. Just after the dawn, a luminous meteor, or fire ball, apparently one half or two thirds as large as the moon, rose from the horizon in the north, and, proceeded with great velocity, and a waving motion nearly to the zenith; it was distinctly visible, through the clouds which partly covered the sky, appearing like the sun in a mist; and, when it passed the spots of clear sky, it flashed, with a vivid light, on the beholders, sparkled like a fire brand carried rapidly against the wind,

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* A stone is preserved in the museum of Bordeaux, which, in 1789 or 1790, fell through the roof of a cottage, and killed a herdsman and some cattle.

discovered a waving conical train or tail of paler light; and, at length with three loud and distinct explosions, like those of cannon; with as many leaps, and a rapid succession of fainter reports, like those of musketry, and a decay of light somewhat gradual, disappeared. This meteor was seen from Vermont to the city of New York, and over an extent of two or three hundred miles from New Jersey, to Salem in Massachusetts. Masses of stone were projected from it, at each of the three principal explosions; they were scattered over an extent of ten miles in length, and three or four in breadth. One mass fell within a few yards of a man who was standing at his door; it was dashed to pieces on a rock; a piece as large as a goose egg remained unbroken, and was warm half an hour after the fall. A stone of 35 pounds fell in a door yard within a few feet of the house; it buried itself completely, in the ground, at the depth of two feet. Two other stones, one of about 8 or 10 pounds, and the other of 13 pounds, fell in the fields near the same house. Two miles south, two other stones fell, one at the foot of Tashowa hill, and, the other upon it; the former weighed about 20 pounds, and the latter 36 1-2 pounds; they made deep holes in the ground. At the last explosion, a mass of stone was projected, which must have weighed at least 200 pounds; it descended with a roaring noise, and a visible curve of light; struck a rock with a great concussion, dashed it, and was itself dashed in pieces, tearing a hole in the ground, on to which it glanced, of 5 feet long, 3 feet deep, and 4 1-2 wide. In all the instances there was a whizzing or roaring noise in the air, when the stones descended, and an evident concussion of the ground, when they struck. All the most important facts were witnessed by numbers of people, who never before heard of the falling of stones from the atmosphere.

Since this event, a large stone of between one and two hundred pounds weight has fallen in Russia, and, on the whole, there is much reason to believe that similar events occur almost every year, and probably have occurred from the remotest ages.

There is such a wonderful similarity in the appearance and composition of these stones, that they are completely different from any other, and yet so similar to one another, that they are readily recognized by the eye of even a careless observer. Those which have fallen in the remotest countries, in the East Indies, in Europe, and America, are almost precisely alike in their external appearance, and chemical constitution.

Where they have not been too much broken to admit of its being observed, they are covered externally with a black crust, rough like shagreen, and proceeding, in all probability from the effects of heat, in producing an oxygenizement and vitrification of the metallic and earthy substances. In their form, they are irregular, but they often exhibit spherical and commonly curvilinear figures. When they first fall, they often smell of sulphur, and are found to be hot if immediately examined. When broken, four distinct sorts or forms of substances may be discovered in them, either by the naked eye, or, by the microscope.

1. Globular and spherical bodies, of a dark brown, or gray colour, hard enough to scratch glass, and to give a few faint sparks with steel; easily breaking under the hammer, and of a compact texture. They are of every

size, from that of a grain of sand, to that of a pea. They lie imbedded in the mass of the stone which appears generally of an ash gray, or light slate colour.

2. There are numerous and often highly brilliant points of pyrites of a reddish yellow colour, very friable, and when powdered, appearing black.

3. Portions of iron in the metallic state, dispersed promiscuously, like the pyrites, through the stone, and varying in size, from mere points to the magnitude of an inch or more.

4. The basis of the whole stone, that which connects all the other substances, and from which they may be detached by the point of a knife, is a granular earthy matter of an ash-gray colour, often inclining to slate, easily pulverized by the hammer and pestle, and, when in small pieces, without much difficulty between the fingers. There is, of course, a considerable variety in the distribution and proportion of the constituent substances, in the earthy cement, and, when it has been wet, spots of iron rust often appear upon the surface. The specific gravity varies from 3,352 to 4,281.

In the stones which fell at Weston, there was a considerable variety in the appearance of the earthy cement; some parts of it were light coloured, almost white, and of regular forms, as if those parts had once been a crystallized substance. In the composition of these stones there is such a surprizing coincidence, as, in connection with their physical characters, and the phenomena which attend their appearance, must render it in the highest degree probable that they have a similar origin. According to Mr. Howard, a stone which fell at Benares, consisted, in its different parts, of the following ingredients.

The pyrites contained,
2.0 sulphur,
10.5 iron,
1.0 nickel,
2 0 earths, and foreign bodies.
15.5

The spherical bodies,
50,0 silex,
15,0 magnesia,
34,0 oxide of iron,
2,5 oxide of nickel.
107,5

The earthy cement,
48,0 silex,
18,0 magnesia,
34,0 oxide of iron,
2,5 oxide of nickel.

The stone of Yorkshire, when deprived as much as possible of metallic masses, gave Mr. Howard the following proportions in 150 grains:

75 silex,
37 magnesia,
48 oxide of iron,
2 oxide of nickel.
162

The increase of weight was occasioned by the addition of oxigen to the metals.

The stones of L'Aigle yielded to Vauquelin and Fourcroy:

54	silex,
36	oxide of iron,
9	magnesia,
3	oxide of nickel,
2	sulphur,
1	lime.
105	

The stone of Ensisheim gave the same analysts;

56,0	silex,
30,0	oxide of iron,
12,0	magnesia,
2,4	nickel,
3,5	sulphur,
1,4	lime.
105,3	

The stones which fell at Weston in 1807, gave according to my analysis,

51,5	silex,
38,	oxide of iron,
13,	magnesia,
1,5	oxide of nickel,
1,	sulphur.
105	

Thus we see that the stones consist, invariably, of silex, iron, magnesia, nickel and sulphur; the silex constitutes generally about one half;—the iron from a quarter to a third, and sometimes more; the magnesia from a tenth to a sixth, and that the sulphur and nickel are in very small proportion.

The lime mentioned in two of the analyses is probably accidental, and the existence of chrome has been asserted by Saugier, but, this has not been confirmed by other chemists.

As to the origin of these bodies, the subject is involved in such obscurity that no satisfactory *conjecture*, not to say hypothesis or theory has been as yet advanced. There is however some difference in the degrees of improbability, attached to them respectively. All that deserve any attention may be included under the following heads:

1. The meteoric stones are formed in the atmosphere.
2. They are thrown from the vulcanoes of this earth.
3. They are ejected from those of the moon.
4. They are thrown from terrestrial comets.

The mere existence of so many hypotheses is sufficient to prove, that we have no real knowledge on the subject. A few remarks on each of these suppositions will suffice to show that it is much more easy to raise objections than to substitute a satisfactory explanation.

1. As to the atmospheric formation of these bodies. Of the ingredients found in these stones, sulphur is the only one ever known to be in the state of vapour, and the proportion of this found in the various meteoric stones that have been analysed, is extremely small. Silex and magnesia are not only not volatilizable, but, they are infusible; iron and nickel require the most violent degrees of heat to become fluid, and probably can never have more than a momentary existence in the state of vapour, even in the most powerful furnaces. How is it possible then that these substances should get into the atmosphere in the state of vapour, or gas, and, if possible, why have they never been found in the air when it has been analysed?

Since the discovery of Mr. Davy that several of the earths have very combustible metallic bases, he has suggested that these bases may come into the atmosphere in a metallic state, and there take fire; but, if the decomposition of silex had been satisfactorily effected, which it has not, still this explanation would be embarrassed with difficulties which must attend the theory of the atmospheric formation of the meteoric stones, even allowing it possible for the materials of which they are composed to exist in the air, in the state of vapour or gas.

Should they combine in the air, is it credible that they would rush from great distances to one point, and there form a large solid body; would they not rather be precipitated in small masses or flakes like snow or hail? Hail is never precipitated in masses weighing hundreds of pounds; on the contrary, hail stones do not often exceed a few ounces in weight, and we have every reason to suppose that the region in which they are formed is often filled with aqueous vapour, where corpuscular attraction, could it ever exert such an extensive agency upon aeriform particles would produce a great aggregation of matter. These difficulties are much increased, when we consider that some of the meteors from which the stones have descended, have been hundreds and sometimes thousands of feet in circumference; this is admitted by the best astronomers and philosophers, and is capable of being satisfactorily shown from deductions drawn from their apparent diameter, and the time that has elapsed between the extinction of the luminary at the explosion, and the arrival of the sound to the ear of the observer.

But, even waving all these difficulties, how could these meteoric bodies acquire their prodigious horizontal velocity. If formed in the air, they would descend rapidly in lines perpendicular to the horizon; but their motion is nearly horizontal, and it could not be communicated by the air; for, "the progress of the most violent wind is not more than two or three miles in a minute—but, a meteor moves several hundred—the velocity of sound is less than 1200 feet in a second, that of a meteor more than 20,000—the greatest force of gunpowder will throw a cannon ball but a very few miles while a meteor is often seen to move several hundred." Other objections might be urged against this theory, but these are sufficient to prove that it is untenable.

2. Their origin from terrestrial volcanoes is still more improbable. Th composition and appearance of the stones is different from that of any known

volcanic substances; the stones have fallen hundreds and even thousands of miles from volcanoes; distances to which it is impossible that they should be conveyed, by any force that can be exerted at the surface of the earth, and, when it is considered that the stones which have come down to us are merely minute portions, torn off from the great meteoric bodies, which have continued to move on after the rupture, and had they fallen, would have been of sufficient size in some instances, to have filled the craters of the largest volcanoes, this theory must be regarded as inadmissible, and, indeed, at the present time, I believe it has no advocates.

We are not assuming one theory to oppose another, for, luminous meteors, which have apparently exploded, and been extinguished, at the moment when atmospheric stones have fallen, have appeared in so large a proportion of the instances that are best attested, and most minutely described, that, notwithstanding some cases have occurred where the stones have apparently proceeded from burning clouds, and no fiery globe has been observed, still these appearances were probably the effect of optical illusion, or of the presence of the sun's light, and we are sufficienly authorised to conclude that atmospheric stones proceed from luminous meteors passing rapidly through the air, and no theory can be satisfactory which does not account for both.

3. Their ejection from lunar volcanoes, although supported by one of the most distinguished of the French Philosophers, and countenanced probably by a majority of the men of science in Europe, appears to be hardly more tenable than the two preceding theories. It is admitted to be possible, that if a body were thrown from the moon with a force of about ten thousand feet in a second, it might pass the point of equal attraction, which is about twenty four thousand miles from the moon's centre, and, then, if the earth and moon were relatively at rest, it would come in a right line to the earth's surface; but, as the moon and earth are both moving forward in their respective orbits, the path described by a body projected from the moon would be a curve, the result of the composition of the motion of the moon in her orbit, the projectile force, and the power of gravitation, and, the body would therefore probably revolve around the earth; if by any means pieces were detached from it, they would fall to the earth and thus the theory appears to be possible, if we take into view only those insignificant portions of the meteoric bodies which come to the earth. Philosophers seem to have employed themselves principally in accounting for these, without taking into consideration that they are mere atoms of the bodies from which they have come. The body of a meteor is a firm compact substance, for no other could preserve the correct globular form in moving so rapidly through the atmosphere; and their light is usually well defined, so that hundreds and thousands of people who have seen them at once, give substantially the same account as to their apparent magnitude; hence there is good reason to conclude, that the estimates which have been made of their magnitude have not been much overrated. Dr. Herschell estimates the altitude of the lunar mountains as being generally not more than half a mile; now is it credible, that bodies whose diameter is from two or three hundred feet to half a mile, should be projected from lunar volcanoes, and with such force as to go be-

yond the common centre of attraction, and arrive in the atmosphere of the earth? Indeed, if it may be permitted seriously to combat so extravagant a supposition, would not the re-action upon the moon itself produce a violent explosion of her own sphere, as a gun is burst by an over charge. We do not know the composition of the moon, and it may, for ought we know, be uniformly composed of silex, iron, magnesia, sulphur and nickel, but, this is in the highest degree improbable; yet as the meteoric stones are all of similar composition, the theory implies this, while we know that the lavas and other volcanic matters of our own earth are composed of the most various ingredients, and are often very dissimilar from each other.

Probably, not a year elapses without a meteor's being seen in some part of the world, and, had they been of lunar origin, no small part of that satellite would, ere this, have been shot off in meteors.

4. Their origin from terrestrial comets, is the only one of the theories which remains to be considered. That the earth may be attended by a system of inferior satellites corresponding to the solar comets, has been frequently suggested by philosophers; but, we are indebted to the Rev. Thomas Clap, formerly president of Yale College, for an elaborate consideration, and a minute application of it to the explanation of the phenomena of meteors. This gentleman left behind him a paper containing "Conjectures on the nature and motion of Meteors." It was considered by its author as an unfinished treatise, but, it was published some years after his decease, and, although it does not appear that the learned author was acquainted with the falling of stones from the atmosphere, (for this subject had not then attracted the attention of philosophers,) this circumstance, instead of invalidating his theory, would have brought a great accession of strength to its support.

President Clap had it in view merely to account for the fire balls usually denominated meteors.

The explanation was founded upon an analogy drawn from the solar comets—particularly, from the eccentricity of their orbits, their consequent near approach to the sun in their perihelion, their prodigious distance at their aphelion, and the long course of time, in some instances hundreds of years, which they take to accomplish their revolutions. "President Clap supposed (see Professor Day's VIEW) tha tthe earth is furnished with its system of comets, as well as the sun—that their size, and the period of their revolutions are proportioned to the comparative smallness of the primary body, about which they revolve—that, like the solar comets, they move off in very elliptical orbits; and, during the greatest part of their circuit, are too far distant to be visible—that, in their approach to the earth, they fall within our atmosphere— that, by the friction of the air, they are heated, and highly electrified—that the electricity is discharged with a very violent report—that they then move off in their orbits, and, by their great velocity, are soon carried out of our sight."

The appearance of the meteors is such as corresponds very well with this view of the subject.

The dimensions of these bodies, the rapidity of their motion, the direction of their course, the proportion which they bear in size to their central body the earth, being about the same as the little planets, recently discovered between the orbits of Mars and Jupiter, have to the sun, about which they revolve, all accord perfectly well with the supposition of planetary bodies moving through the lower part of their orbits, and not at all, with what might be expected from matter falling from condensed gases or vapours, or projected from lunar or terrestrial volcanoes.

It is calculated, that, if a body moving horizontally near the earth, have a velocity of less than 300 miles in a minute, it must fall to the earth—if, of more than 430, it will, if undisturbed by other bodies, fly off in an hyperbola, and will never return.

Adequate allowance being made for the resistance of the air, and the motion of the earth, a body will, within these limits, revolve around the earth in an ellipsis, and return at regular periods.

Now, it is very remarkable that the velocity of such meteors as have been observed is generally rather more than 300 miles in a minute, that is just enough to carry them clear of the earth and yet so small as to bring them within its atmosphere, while moving through the lower parts of their orbits.

Granting the existence of these bodies, and, that their motion is such as has been described, it is easy to see that any cause which might produce a rupture or explosion of a part of their substance, might, very naturally, throw fragments to the ground, and, the circumstances which have, in numerous instances, actually attended *their descent*;—its rapidity, proved by the holes which they make in the earth, the whizzing or roaring noise, and the violent concussion; its *irregularity*, the fragments being scattered over several miles of territory, which is what we might expect from the effects of a violent explosion; its happening immediately after explosions actually heard from the fire ball and after the extinction of its light, and the minute proportion which the fragments bear to the whole body of the meteor;—all these circumstances considered together cannot leave a doubt that in numerous instances, at least, the stones have been thrown off, from a large solid body moving rapidly through the atmosphere. But, the stones bear no sensible proportion to the whole meteoric mass, and, this must be supposed to move on in its orbit, scarcely disturbed by the trifling loss which it has sustained, and, no longer luminous, because the heat and electricity have been, in a great measure dissipated by the explosion.

There is nothing inconsistent with analogy in supposing the existence of numerous small planetary bodies in the solar system; they may be necessary to adjust the balances of motion and attraction, and, they may well enough be of an uniform, and sterile composition, since no analogy would lead us to suppose them inhabited, or even habitable. This conjecture derives confirmation from the discovery within a few years past, of several very small planets, in the solar system, where they had never been suspected before.

Upon this view of the subject, it is highly probable that meteoric stones have fallen, in every age of the world, and that this phenomenon will frequently occur again.

The theory of president Clap, with the addition which has now been stated, appears to be liable to only two objections, of much importance.

It may be said, that it does not account for such appearances as that of Sienna, and a few similar ones, where the stones have seemed to proceed from a burning cloud. Under such circumstances of terror and amazement, there is much room for optical deception, and, perhaps we are not justified in concluding, that a meteor may not illuminate a cloud, by which it is in part concealed.

The other objection is founded on the apparent inadequacy of the cause assigned by president Clap, for the ignition of the meteors ; it remains yet to be proved, that mere friction with the air is sufficient to produce strong ignition in a solid body, or to excite electricity enough to generate that effect, and the attendant explosion.

The explosion might however be owing, not merely to an electrical discharge, but also to the expansive force of vapours and gases, suddenly and powerfully rarefied by heat.

With these qualifications, the origin of meteoric stones seems to be better explained upon this, than upon any other scheme, but, as yet it can be regarded only in the light of an hypothesis, recommended by the felicity with which it explains most of the phenomena. Should one of the meteors ever approach the earth, without sufficient projectile force to carry it clear of our planet ; its fall would be inevitable, and those philosophers who are so happy as to witness such a catastrophe, uninjured, will have better means than we now possess, for constructing a satisfactory theory on this obscure, but highly interesting subject.

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