A

MANUAL OF CHEMISTRY,

ARRANGED FOR

NATIVE, GENERAL AND MEDICAL STUDENTS, AND
THE SUBORDINATE MEDICAL DEPARTMENT
OF THE SERVICE.

BY k

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PREFACE TO THE FIRST EDITION.

The following pages have been compiled with the view of supplying the Native Student and the Subordinate Medical Department of the Service with such a Manual of Practical Chemistry as will, in some measure, prove a substitute for the costly and unattainable class-books of Europe.

While the price of any one of the really valuable works alluded to is far beyond the means of the pupil, there is again not one of them which treats of the subject in the manner which my experience as a teacher in the Medical College of Calcutta has shewn me to be best suited to the habits, resources, and objects of the Indian Student. These works have been written for a people amongst whom education is widely diffused, to whom the leading truths of physical science are familiar, and who have long discarded the ancient notions regarding the elementary bodies.

The writers were in such a case warranted to a certain extent in adopting the order of arrangement by which their works are characterized. Accordingly we find them, in the first instance treating of Heat, Light, Electricity, Galvanism, and Electro-magnetism,—subjects which can only prove intelligible to persons having an extent of preliminary knowledge of the elementary bodies, which no native student possessed but two years since; and which few, indeed, have to this moment acquired. In my lectures, as in this manual, a different order was obviously necessary. The elementary bodies were first to be taught—the general laws of the sciences above specified could only be subsequently considered.

Again, the standard works of chemistry in Europe were obviously unsuited to students destitute of regular apparatus, and solely dependent for the prosecution of experiments on the chance resources of bazar implements and materials; in a country where there is not a single glass-house—but one acid manufactory—where the simplest chemical tests are sold but at the three metropolitan cities, and that at such prices as place them completely beyond the reach of all but very affluent amateurs.

In the subsequent pages I have endeavored to the best of my ability to meet this evil. I have throughout, as far as practicable, described cheap and easily constructed substitutes for the formal and expensive apparatus of Europe. I have pointed out the ores and other crude materials from which chemical preparations may be made, and adapted the various processes described to the circumstances and opportunities of the student. In the Appendix I have inserted, moreover, such copious details relative to the art of glass-working on the small scale, that an adroit, intelligent student can readily manufacture *himself* all the *essential* instruments he requires.

Throughout this little work I have strictly avoided reference to obsolete notions and abandoned theories. Every instructor is aware how much less difficult it is to teach ascertained truths than to combat, or even explain, erroneous doctrines.

On mere popular chemistry,—that which relates to amusing and shewy experiments alone,—I have given no information. I am not anxious to be entertaining: my sole object is to convey instruction. Moreover, such details would have excluded really important facts from a volume of necessarily restricted dimensions.

On the whole, I have endeavored to render this volume a sufficient guide for such general and medical students as may be destined to fill situations in which the offices of practical chemists may occasionally be demanded of them.

The work I have chiefly followed, is the last edition of Dr. Turner's Elements, the order of arrangement in which I have adopted as far as the plans of both volumes correspond. Reid's Practical Chemistry supplied me with many valuable directions as to the exact manipulation of numerous experiments. I have had free recourse to Dumas's great work in French, on the Chemistry of the Arts, for *details* relative to several manufacturing operations, for instance, in the preparation of sulphuric acid, washing of crude alkalies, saltpetre, &c. which are unnoticed in any elementary volume in the English language. Lastly, from the *Annales de Chimie, Journal de Pharmacie,* and other periodicals, I have selected every new fact connected with the progress of the science since the publication of Dr. Turner's last edition in 1835. As instances of these additions, I may allude to Saussure's new and excellent process for analyzing the air, (*Journal de Pharmacie, Sept.* 1836 ;) Koene's cheap method for preparing Creosote, (*Annales de Chimie, Jan.* 1836 ;) Marsh's process for detecting Arsenic, (*Jameson's Journal, Aug.* 1836 ;) Mr. Knox's experiments on Fluorine ; Thillorier's discovery of the solidification of carbonic acid ; Dr. Gregory's process for preparing the mineral chameleon ; Dr. Thomson's new method for analyzing manganese ores ; Mullin's cheap Voltaic Battery, (*Philosophical Magazine, Oct.* 1836 ;) with a variety of other papers.

While condensation has been my chief aim throughout, I have, on some subjects, given details of very unusual length in a mere elementary volume. On nitrate of potash, the alkalies, sulphuric acid, and opium, for instance, I have entered minutely, owing to the importance of these articles in India. With reference to opium particularly, I have given the results of my own experience in the Opium Department during my service as first Assistant at the Government Factory of Behár, in the hope that the details I communicate relative to the analysis and adulterations of the drug may be of some use to the numerous individuals engaged in that department.

The ample information in the Appendix, relative to the *detection of poisons,* I have been induced to insert by my knowledge of the extraordinary frequency of murder by poisoning in this country. On this subject scanty details would be worse than useless; for of all chemical inquiries, those relating to medico-legal analysis in cases of poisoning must be conducted with the most scrupulous and methodical accuracy.

The Hindustání names of such chemical articles as the student can procure in the bazars are inserted in the Native character under their several heads. Persian and Bengálí synonyms are also occasionally given.

PREFACE TO THE SECOND EDITION.

The Author has carefully corrected such errors as had crept into the first Edition, and he has added every important fact, which the progress of science rendered necessary to the Medical Student. Several additions have been made to the sections which treat of the preparation of many articles of local value. An outline of "Chemical Electricity" has also been added. The coarse lithographs appended to the first Edition, are replaced by highly finished copper plates. In short, no pains have been spared to render the little work what it was originally intended to become,—a suitable Class Book for the Schools in India, and a useful epitome for the Medical Practitioner and Chemical Manufacturer.

INTRODUCTION.

As the study of Chemistry is but a subordinate branch of the great system of science to which the name of Natural Philosophy has been applied, it will facilitate the object I hold in view, if we occupy a few moments in considering the proper import of those terms.

Natural Philosophy in ordinary language means nothing more than the science or knowledge of natural *truths*. It embraces thus every *fact* in the phenomena of the universe, which our intellect is capable of comprehending, and of arranging in similar groups referable to the same or to analogous causes. These causes may be unknown, but their effects are obvious; so much so indeed, that a clue to their proper classification may be found in the proposition —that all the material masses in nature are composed of indestructible particles or *atoms*, combined or held together by *attraction* of various kinds, these particles being in themselves *inert*, or incapable of changing their state of motion or of rest. These few great truths lead to a ready comprehension of the nature or constitution of the masses of the universe, of the movements occurring among them, and of the laws by which they are governed:—and even when we leave the comparatively narrow circle to which a contemplation of mere material and terrestrial phenomena would restrict us,—when, for instance, we investigate the nature of heat, and light, and electricity, and magnetism, and when we ascend to the sublimest of all studies, that of the movements of the heavenly bodies,—these truths still point to the path by which our investigations may be pursued with the greatest facility and success.

As it is under the head of attraction that Chemistry becomes a department of Natural Philosophy, or of the knowledge of natural truths, it is desirable to enumerate here the leading varieties which the natural forces of attraction present. We have thus the attraction of *gravitation*, which causes all bodies to move towards each other in proportion to their mass, as substances fall towards the earth, as the tides obey the approach of the moon, and by which the heavenly bodies are balanced in their perpetual career through space. Again, there is the attraction of *cohesion*, by which two smooth and uniform substances, such as polished metals or glass, or divided Indian rubber, adhere together; and lastly, the *electric* attraction, to which as it embraces the *magnetic* and the *chemical*, I shall advert in more detail.

Without entering into minute statements, which to the majority of students would prove unintelligible in this place, a few remarks will sufficiently explain what is meant by the words *electric attraction*. When a piece of glass or wax, or of many other substances is rubbed by silk, it is found that it acquires the power of attracting or drawing towards it various light bodies in its vicinity.

Now in these experiments the attracted substances undergo no change of properties. Their colour, form, consistence, &c. &c. remain as before. To this then the *specific* name of *common electric attraction* is given to distinguish it from the next which may be called the *polar* or *magnetic,* because under its influence bodies are disposed to place themselves in a determinate position with regard to the cardinal points of the earth, pointing N. S. E. or W.; and while so affected they have the additional property of attracting iron and a few other substances with great power. The common *magnet* or compass needle points nearly to the north and south, and powerfully attracts iron. The cause of this polarity and attraction remained for ages one of Nature's most mysterious secrets, but the splendid discoveries recently made by Oersted and Faraday unequivocally prove that the magnetic is but a species of electric attraction. They have shewn, that whenever an electrical current is established in a certain direction in any metallic substance, that substance tends to place itself in the same direction as the magnetic needle or mariner's compass, and it attracts masses of iron in the same manner. An electric current being thus excited in two minute plates of zinc and copper, and made to circulate through a wire of copper, silver, or gold, immediately renders it a magnet of great sensibility.

Such are two of the varieties of electric attraction. The third is the *chemical*, which differs remarkably from the other species enumerated. It only acts at insensible distances; it changes the secondary properties of the bodies between which it operates, and thus gives rise to the endless variety of colour, form, and fabric, which by means of a few simple substances, only 54 in number, renders the constituents of this globe the inexhaustible source of happiness and delight to mankind.

The science of Chemistry is that, then, which examines the relations this species of attraction or affinity establishes; which ascertains the nature and constitution of the compounds thus produced, and which determines the laws by which its action is guided.

The domain of the science may thus appear to be what in truth it is, of vast and almost infinite extent; nevertheless, its study presents facilities which soon enable us to master its details. Between Chemistry and the study of a language previously unknown to us, a striking analogy may be traced. The words of the language, however numerous, are composed of but a few letters. We learn the forms and sounds of these letters to associate them in words, and these words again we can analyze and divide into their original elementary constituents. Thus it is with the materials of this world: we look around us, are amazed at its grandeur and diversity, and our senses are confused as when we open a volume in an unknown tongue. But experiment and analysis effect for the chemical philosopher what grammars and dictionaries accomplish for the linguist. The difficulties of both pursuits soon vanish, and the original chaos is marshalled into a system of perfect simplicity and order.

Having thus endeavoured to explain and illustrate the *abstract* nature of Chemistry, I shall next attempt to point out some of the practical applications of the science, its importance as a branch of general education, especially for the natives of this country, and, above all, its essential, its vital necessity to the medical student.

As a department of the general student's education, the knowledge of the properties of the simple substances and their compounds is fraught with manifold advantages; of these, one of the most valuable is its peculiar tendency to the formation of habits of sober and philosophical reasoning. Its very essence being the discovery of the qualities which distinguish one material substance from another, it trains the student by an insensible but irresistible power in the discrimination of truth from error in all its relations, whether metaphysical or material. It is, in fact, one of the best systems of practical logic a youth can learn. It teaches him how to observe and appreciate the minutest shades of difference, as well as the widest generalization of facts; and it does this, not by an appeal to our mental faculties alone, not by the dry comparisons of the sides of triangles or diameters of spheres, but through the channels of all our perceptions and senses. On the first occasion of my addressing the classes of the Medical College, I quoted, in support of these opinions, a passage from an essay by Mr. Parkes, which seems to me to bear so appropriately on the subject, that I may perhaps be excused for referring to it again. In alluding to the use of Chemistry as a syllogistic system alone, Mr. Parkes emphatically says—"It may be remarked, that it is the necessary consequence of this study that it gives the habit of investigation, and lays the foundation of an ardent and inquiring mind. If a youth has been taught to receive nothing as true but what is the result of *experiment*, he will be in little danger of being led away by the insidious arts of sophistry, or having his mind bewildered by fanaticism or superstition. The knowledge of facts is what he has been taught to esteem, and no reasoning, however specious, will ever induce him to receive as true what appears to be incongruous or cannot be recommended by demonstration or analogy."

But it is not merely on these moral grounds that I would seek to establish the importance of the study to the general native student; other, and perhaps more persuasive, reasons may be laid before him. By becoming proficient in this science, he learns the certain means of obtaining lucrative employment and considerable distinction. We are in India situated in the vicinity of many territories to which Europeans are denied access, and which a scientific eye has never yet explored. These are open to the ingress of our native fellow subjects, but they know not how to make the observations which chiefly render travels of scientific interest or utility. If possessed of due knowledge of chemistry and natural philosophy, the native traveller would enter these unstudied regions and view them as he would a book in a familiar tongue. He could ascertain the heights of their mountains, the nature of their soils, the character and value of their mineral riches, the composition of their drugs and dye stuffs, and all this with an apparatus not worth one hundred rupees. But not to step beyond the limits of our own possessions, we might point to climates and localities where a European dare not venture, but where a native may reside with impunity; where rich mines of the precious metals, as well as of copper, iron, tin, and lead have been discovered,—but which remain utterly profitless through the extreme ignorance of the natives of the mode of working the ores. In illustration of what can be effected in this department, I may mention that in a series of specimens sent to me from a native copper-mine in Kemaon, the mere slags (or the part considered as waste by the workmen) were richer in copper than many ores which are turned to great profit in the hands of educated men. Under such a system, native mining must be indeed a very useless calling; while, if prosecuted by persons trained in chemistry for a few months, it would become a fertile source of national and individual emolument. Analogous cases are so numerous that they would occupy a volume to detail them.

In the manufacture of glass, porcelain, and various kinds of pottery; in the production of saltpetre, the cultivation of opium, the growth and purification of drugs and dye stuffs, for the wholesale market, the same wide field exists, in which numbers of young men would find lucrative employment, and would, moreover, be the source of inestimable benefit to their countrymen, by disseminating among them the knowledge of the improved processes by which the value of the manufactures alluded to would be enhanced beyond calculation.

Such are a few of the useful applications to which the general student may turn this captivating science. It is one, moreover, which the humblest mind can sufficiently comprehend and avail itself of; while to the highest and most gifted it affords unbounded scope for the employment of all its endowments. Duly impressed with the necessity of disseminating such valuable knowledge, our most patriotic and enlightened statesmen and other individuals of high rank in England, have, within the last few years, lent all their influence to the establishment of Mechanics' Institutes throughout the manufacturing towns; in these institutions regular lectures on chemistry are delivered, and crowds of humble citizens receive gratuitous instruction. The result is already known. From the ranks of the workman and the mechanic have sprung up a multitude of men of genius, whose endowments would otherwise have been utterly lost to mankind. Every art and manufacture has already felt the impetus of this mighty force of education; inventions are daily patented, and their practicability proved, which but a few years since were merely talked of and laughed at as idle chimerical dreams. Indeed the progress of improvement becomes so rapid and extraordinary that it is difficult even to speculate on the limits within which human ingenuity will ultimately be confined.

But even here I cannot close the enumeration of the motives which should influence the *general* student in the prosecution of this study. I am aware that among native pupils there are some young men whose affluent circumstances place them beyond the necessity of turning chemistry to purposes of emolument, and who perhaps may reasonably feel no ambition for distinction in this or any other science. But even to such students I can hold forth inducement enough in the mental gratification every rational being must derive from the views this study communicates of the beauty, the simplicity, and the design which pervade all the natural phenomena around us. A lecture I once attended at the Royal Institution of London may well illustrate this position. The lecturer treated of the nature and properties of the air,—of the atmosphere we breathe.

He took a portion of the air of the room in which the audience was assembled. He analysed it, and shewed that in that invisible impalpable fluid there were two different gases; these gases again he extricated from other substances, and, imitating nature's own processes, *he formed* *atmospheric air*. By appropriate experiments he caused mists and clouds to float in, and miniature lightnings to play through the air he thus created. He caused iron to burn like tinder in one of its elements, and by the combustion of lime produced a light as intolerable to the eye as the rays of a noon-day sun. Water he shewed congealed in a few moments as if by winter; he then separated its elements, and made them re-unite with an explosion like the thunder, and such heat that flint and agate melted before it like wax before an ordinary fire. To crown the demonstration, he lastly exhibited the same elements in another form, impelling a steam engine with the power of an elephant, but obedient to the finger of a child. The audience on that occasion were composed of many distinguished noblemen, jurists, military officers, divines, and other individuals of *general* education, and all seemed equally delighted with what they had witnessed. If, then, this science discloses such attractions, that it is followed with avidity by these distinguished classes of society, the native general student may with confidence become their imitator in this as in many other pursuits.

But if Chemistry be thus profitable and gratifying to the *general* student, the *medical* student derives from it such inestimable benefit, that I feel bound to point out in some detail the leading applications of the science to medicine and its tributary pursuits.

Though the nature of *life* is yet utterly unknown, and perhaps altogether inscrutable, we find that in the living body there are constantly taking place numerous chemical actions essential to its animation. Of these, one of the most important is *respiration*, or breathing.* Chemistry has long since pointed out that the air we breathe is not, as the ancients thought, and as the uneducated still believe, an elementary or simple substance, but is composed of oxygen and nitrogen gases, with small quantities of an air called *carbonic acid;* and it has further proved the extraordinary fact, that it is the *oxygen* alone which supports our breathing, and thus maintains our lives. The *nitrogen* lends no assistance to the function; but most strange of all, the *carbonic acid*, which exists in the air we are every moment respiring, is a poison of such power that if it was present in the proportion of but *one* to *four* parts of the air, every animal of the higher classes would instantaneously perish. By various natural and artificial processes this poison is produced abundantly on the surface of the globe. In many places it accumulates rapidly to the imminent danger of those who approach incautiously. A moderate knowledge of chemistry, however, enables us not only to ascertain when its proportion becomes too great, but when this has happened to render it perfectly harmless. It leads us too, by our knowledge of the cause of the accident, to efficient means of treatment and cure.

To return to another and equally important application of the science in medical pursuits—in the *digestion* of our food it has revealed the elements which most contribute to the nutriment of animals, and explained many of the wonderful changes by which our food is converted into blood and flesh and bone identical with our own. It has taught us how to relieve many painful and dangerous diseases of the digestive organs by strictly chemical means; and it has shewn mankind how to extract wholesome, palatable, and nutritious food from many substances long supposed to be destitute of utility.

In diseases of the urinary organs, again, in stone and gravel for instance, a knowledge of Chemistry is indispensable. The stones formed are of different kinds,—in fact of opposite constitution. Some are dissolved, or their formation prevented, and the patients cured by means of remedies, which would, to a certainty, have the effect of aggravating the disease were the stone of a different chemical constitution. In short, if we understand Chemistry, we can cure many cases of stone, and thereby spare our patients a dangerous and awful operation; but if we are ignorant of that science, our remedies will, in all probability, make the disease infinitely worse than before.

Again, the blood and its secretions are only understood by the chemist, and he applies his knowledge of their composition to practical uses of the utmost importance. In some diseases, for example, the blood undergoes changes which chemistry alone can explain; and by this explanation we are guided in our research for appropriate systems of cure.

Under the section which treats of the blood, the student will find a remarkable proof of the truth of this assertion.

There are still many other departments of medicine, in which Chemistry is equally essential and valuable.

Among the foremost of these, especially in this country, is the study of the chemical composition of the medicines used in surgical and medical practice.

Some of the most powerful medicines we possess, such as calomel and the other compounds of mercury, lead, antimony, copper, iron, &c. are exclusively artificial preparations, all easily, cheaply, and well made by those who understand chemistry, but only obtainable at enormous expense by persons uninformed in that science. In every bazar in India the raw material is to be found from which all these valuable remedies, from the use of which the population is now debarred, can, I repeat, be easily prepared. But we require practical chemists to accomplish this national object; mere book chemistry will not do. In proof of this I need not adduce more than a solitary fact. The substance called *súrmá*, or sulphuret of antimony, which is cheap and abundant in every bazar, is the source from which all the invaluable preparations of antimony—for instance, *tartar emetic*—are manufactured. Now, on referring to Dr. Ainslie's work on Indian Materia Medica, we find that able author stating, that what is sold for *súrmá* is usually sulphuret of *lead*, not of antimony. The practical chemist alone could decide this question, and on analyzing the *súrmá* of the bazar, I found not only real sulphuret of antimony, but the best and purest I ever met with.*

Again, there are many valuable medicines, such as Peruvian bark, composed of a small quantity of an active remedial principle, mixed up with much useless or even prejudicial matter. From this bark the chemist has extracted Quinine, by which we now can master most of the fevers of this country, rendering it to the wealthy and the great, practically on a par in salubrity with many more favoured climates. But this Peruvian bark and Quinine and other similar valuable remedies are imported only from Europe or America, at an expense which renders them unattainable by the poor inhabitants of this country. I have still too firm a faith in the providence of Nature not to believe that she has been as bountiful to India as to Peru. Though our jungles and forests exhale miasmata, they are doubtless productive of febrifuge vegetables also. I look with confidence to the indigenous materia medica for a substitute even for the inestimable quinine. The inquiry is already proceeding under the most favorable circumstances, and ere long I trust the discovery will be established, which would be fraught with inappreciable good to millions of our poor Indian fellow subjects. This once accomplished,† we shall, in India, if a class of native practical chemists be

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* Dr. Ainslie is however right in saying, sulphuret of *Lead* is usually sold, instead of *súrmá*.

† It has been accomplished since the first edition by the introduction of the use of *Narcotine*.

brought into existence, be almost independent of any other country for the remedies required in the practice of medicine.

It is almost unnecessary for me to pursue any further the uses of Chemistry to the medical student. I will only allude to one topic more. There are numerous and very powerful poisons rapidly proving fatal when taken in a certain quantity. I may mention prussic acid, barytes, oxalic acid, corrosive sublimate, caustic potash, oil of vitriol, &c. as instances; these and many others Chemistry renders perfectly harmless by pointing out antidotes, which, if administered in proper time, are the certain means of saving life. To Chemistry again we turn in cases of murder by poisoning, to enable us to detect the substance used, and bring the murderer to justice. The nicety with which, in many cases, this science enables us to accomplish this important end, will be judged of when I state that a very little practice in the laboratory will enable the operator to detect 100th part of a grain of arsenic, corrosive sublimate, &c. in any mixture that can be presented to him. And, what is perhaps still more pleasing to know, the analyst thus instructed can still more frequently protect innocent persons labouring under false accusations. In truth, a native medical graduate attached to our civil stations could scarcely possess a more useful accomplishment than that to which I now allude; for in no other country is murder by poison so frequently perpetrated, or so often the subject of conspiracies to establish unfounded charges.

This sketch, though superficial, is, I trust, sufficient to awaken in the mind of the native student some interest in the pursuit on which he is about to enter. Difficulties will beset his progress it is true, but to overcome them all, he requires only the qualities which the Indian youth possesses in the most pre-eminent degree. He is quick of perception, patient in reflection, adroit and delicate in experimental manipulation; and with these endowments, his full success in this study may be most confidently foretold.

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PART THE FIRST.

SECTION I.

NATURE OF MATTER, ITS GENERAL AND SECONDARY PROPERTIES—THE VARIETIES OF ATTRACTION ILLUSTRATED—SIMPLE SUBSTANCES OR ELEMENTS, EXPLAINED BY REFERENCE TO THE COMPOSITION OF ATMOSPHERIC AIR.

Having given in the Introduction an outline of the nature, objects, and uses of Chemistry, not as a commencement of the actual study of that science, but with the view of explaining what it was the student was about to learn, I shall now enter on the object itself, beginning with the general properties common to all varieties of matter. These we must clearly comprehend before we can pursue individual details with the least success.

All material substances are possessed of two kinds of properties—physical and chemical. When we learn the former, we are students in what is termed Natural Philosophy. To the latter pursuit the name of Chemistry has been specially applied.

Of the physical properties of matter some are *general*, that is common to, or possessed by every kind of matter without exception;—others are *secondary*, that is, exhibited only by some material substances, and not by all.

The simplest idea we can form of the meaning of the term *matter*, is that every kind or portion of matter, however minute, *occupies space*, and from that particular space all other matter is excluded. The term *extension* is used to describe the former fact, or the occupation of space; and *impenetrabi-*

lity the latter, or that no two portions of matter can occupy one space at the same moment.

These are the two essential *general* properties of matter, but there are some others to be considered also. One is *mobility*, or being moveable; which means, that matter yields to every external force, and is in motion or at rest only as that force acts on it. Thus the moon and other heavenly bodies are seen moving in space, and these motions, we believe, have been from the commencement of time, and will never terminate. Motion therefore is a state as natural as rest, and a body on our own globe, once set moving, would never stop, did not some of the secondary properties of matter, which I will presently explain, interfere and bring the movement to quiescence. For the present, therefore, we will consider matter as perfectly obedient, as far as its motion or rest are concerned, to the influence of external forces.

Extreme divisibility is the next general property of matter, and one to which we should direct our close attention. It is well illustrated by many familiar facts. One grain of gold may be beat into a leaf, which will cover fifty square inches of surface, and contain two millions of points visible by the naked eye, while by magnifying glasses or microscopes we can see a much greater number.

A single drop of attar of roses will evolve perfume perceptible over a large apartment. By appropriate chemical tests we can divide a grain of iron into 250,000 visible parts.

In further illustration of the extreme divisibility of matter, I may instance the results of Ehrenberg's researches, which shew, that in a grain of tripoli there exist one million and a half of the shields of a minute insect—Wollaston's platinum wires, which are so fine as scarcely invisible except in the field of a microscope,—by Marsh's process for the detection of arsenic $\frac{1}{10,000}$th part of a grain of that poison may be easily detected.

But though extremely divisible—indeed beyond the cognizance of our senses, though assisted by the instruments just named—there are many and very convincing facts, which prove that there is a limit to this divisibility,—that at a certain point, the particles of matter can no longer be made smaller. The same facts also shew, that these particles of the divisible matter have peculiar forms, and are of different weights. To these particles the term *atom* has been applied. This word means merely, that which can be cut or divided no further. It would be premature, however, to discuss this interesting part of our subject at present. But we will subsequently find it one which will lead us to the knowledge of great chemical laws, and of facts of the highest practical utility, which would otherwise prove altogether unintelligible.

We have thus seen that matter is composed of atoms or minute particles occupying space; and observation shews us further that all bodies, when left at liberty near the surface of the earth, move towards its centre in straight lines. What it is that draws bodies thither, we are altogether ignorant; but the power that draws them is called the attraction of *gravitation.* Now all bodies are drawn to the centre of the earth with various degrees of force, and the degree of *obedience* to this force, is denominated *weight.* This amount of yielding to terrestrial attraction, or gravity, is readily measured by various simple contrivances, of which a common pair of scales affords an example readily understood. When we place substances of equal weight in opposite scales, neither is drawn to the earth, because the attraction of the earth acts equally on both; but if we remove a single grain from one pair, the opposite scale preponderates, because the earth is drawing it more powerfully than it does the other.

Experience has further proved that atoms which occupy space and possess weight—matter in short, are altogether *indestructible.* No human power has ever succeeded in destroying or annihilating the smallest particle of matter. We can, it is true, change the form of many substances. We can cause water to disappear by boiling: but though it vanishes from our sight, we know that it has not ceased to exist. It is but changed into steam, from which we can again recover it.

A piece of paper can be made to disappear by burning, like coals or wood kindled in a fire : it is *spoiled* as paper, but the *matter* of which it is composed has only assumed another form. This can be proved in various ways. If we place ten grains of the paper in a closed tube weighing 100 grains = 110, and heat this red hot, when it has cooled it will weigh 110 grains still. Or we may collect the gaseous products, measure them, and weigh them, and it will be found that nothing is lost. The great heat has but made the substances of which it was composed to assume forms in which they are less liable to change. Again, a putrefying dead body is changed, but the elements of which it was made up have not been destroyed.

To anticipate a future chapter in some degree, I may here state that most of the objects which we generally suppose destructible—such as wood, animal bodies, &c. are composed chiefly of four of the substances in the list of elementary bodies—namely, oxygen, hydrogen, and nitrogen, which in their natural state are airs or gases, and carbon, which is a solid substance. Now water is composed of oxygen and hydrogen, and air is composed of oxygen and nitrogen; and again, oxygen, hydrogen, and nitrogen have the power, by the assistance of various degrees of heat, of dissolving and combining with the solid substance carbon. When we burn a piece of paper, we see a black substance remaining—namely, carbon or charcoal. We see water collecting on the sides of the tube, and this water we can subsequently prove to be a compound of oxygen and hydrogen. If we smell the tube, we find a disagreeable odour proceeding from other compounds produced by the burning. Lastly, were we to collect all the products of the combustion, and weigh these, we would find that though we had spoiled or burned the paper, not one atom of its matter had been lost or destroyed.

The last general property of matter which I need dwell on is *porosity*. This is a property not of atoms, but of masses of matter, or of many atoms when together. In many substances we can see pores or minute spaces with the naked eye or glasses: when we cannot see them we can prove that they exist in various ways. Iron, for instance, however compact, can be made smaller by hammering or pressure, which could not have been the case, were there not intervals or pores between its solid particles.

These familiar remarks should lead to a correct idea of the general properties of matter. Every object that surrounds us, the air we breathe, the clothes we wear, the food on which we subsist—possesses these properties, or is formed of minute indestructible atoms occupying space, having weight, and being porous; that is, susceptible of approximation by pressure.

But besides these *universal* properties of matter, there are *secondary* characters also which exist in some substances and are absent or different in others. Thus bodies differ in being transparent or opaque, in their colour, consistence, hardness, elasticity, &c.

Of all the secondary properties of masses of matter, the most important to consider are *solidity* and *fluidity*, as these exemplify several of the effects, and will enable the student quickly to understand the leading mode of operation of the two great forces termed *attraction* and *repulsion*, by which all the phenomena of the material world are governed.

We have already pointed out one kind of attraction which acts upon masses or bodies of matter at sensible distances, at very great distances indeed, and which is called the attraction of the earth, or gravitation. A second kind of attraction which acts upon minute particles of matter at infinitely small distances, and tends to make these *cohere*, or keep together, is called cohesive attraction, and requires some additional explanation. It is that power which resists our breaking down a piece of marble or stone, or which prevents a cord breaking when it lifts up a weight—which causes smooth surfaces, such as glass or lead, to adhere together. This form of attraction is modified and governed by heat, and according as the opposite force predominates, matter becomes more or less coherent.

Thus ice is a solid substance; by heating it a little, it is changed into water, and by boiling this is expanded into steam. Mercury, and oils, and various other matters, which are fluid in temperate climates, become solid in high northern latitudes. Again; iron, gold, copper, lime, and other very solid substances, are driven off in vapours when the heat is sufficiently intense. Thus we find that it is owing to cohesive attraction on the one hand, and to the repulsion of heat on the other, that matter exists in solid, fluid, or aeriform state.

But the kind of attraction which we are called on to study with most attention, is that which, from its peculiar nature, is termed *chemical attraction*, or *affinity*.

Like *cohesion*, this force acts only at *insensible* distances, and is thus different from the attractions of gravity, magnetism, and electricity, which act on substances placed at a distance from each other. Again; cohesion only causes two substances to join mechanically and adhere to each other. Thus, in a piece of the substance called *cinnabar* or vermillion (a compound of one part of mercury and two parts of sulphur), every particle however small, is still manifestly a compound of sulphur and mercury. These small particles, being similar to each other, are called *integrant* particles, and each is as perfect vermillion as the mass itself. But the sulphur and mercury being different from each other and from vermillion, are called the *constituent* or *component* parts. Thus the *integrant* particles of this mass are compounds, and are held together by cohesion. The *component* particles are held together by affinity or chemical attraction.—Again, by mechanical means we can separate the *integrant* parts, as when we powder this substance in a mortar; but no mechanical force can divide the *component* parts, the sulphur and the mercury. These are held together by *affinity*, or chemical attraction, and can only be dissevered by the aid of some substance having a greater chemical attraction for one or the other of the elements in the compound.

To students in general this affinity is a matter rather difficult to understand, but the difficulty arises from their attaching an erroneous and vague meaning to the word itself. When I say that mercury has an affinity for sulphur, I merely express the fact that they readily unite with each other, forming a compound of new secondary properties; and when I say that iron or lead has a stronger affinity for sulphur than mercury has, I merely say that iron, &c. unites with sulphur more readily or easily than mercury.

When two different substances unite, or combine chemically, the result is a substance different in many of the secondary properties of matter, as in colour, form, hardness, solidity, fluidity, from the two bodies of which it is formed. Thus mercury is a silver-like fluid metal; sulphur is a yellow solid; uniting chemically they form vermillion—a solid of so rich a red, that this tint of colour is named from the substance in question.

Illustrations of these changes meet us in every step of our chemical studies. Now, we find two gases or airs, solidified when they combine;[*] ice-cold bodies bursting into flames[†] the moment of their union; colourless solids and liquids when mixed together assuming the richest tints,[‡] or the splendid colours of other materials disappearing altogether.[§] We mix a powerful and corrosive acid with an alkali, the touch of which would destroy the skin in a few minutes; and the resulting substance is the salt we daily use at our tables.[||] Such are instances of the changes in the secondary properties of matter which this power of attraction produces.

We often find too that when two substances of but weak chemical attraction or affinity for each other combine and form a new compound, this is readily decomposed by some

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[*] Muriatic acid and ammonia.

[†] Ice and metallic potassium.

[‡] Corrosive sublimate and ioduret of potassium.

[§] Chlorine and solution of indigo.

[||] Muriatic acid and soda.

third substance, which attracts one of the elements of the compound with greater power, and thus leaves the other free.

When three elements only are engaged in this action, one as it were selecting which ever of the others it prefers, and leaving the third unaffected, it is called simple elective or selecting attraction. Thus iron heated with vermillion takes its sulphur and sets the mercury at liberty.

There are, again, instances where two compounds, each containing two ingredients, decompose each other, and a mutual exchange takes place. Thus chalk or *chunam* is composed of two substances, carbonic acid and lime; and *nowshader*, or muriate of ammonia is composed of muriatic acid and ammonia. If chalk be mixed with nowshader the muriatic acid takes the lime, and the carbonic acid the ammonia, and two new compounds—carbonate of ammonia and muriate of lime are formed, the nowshader and chunam being mutually decomposed. This is called *double elective attraction*.

Affinity, whether simple or double, like other kinds of attraction, is modified by various causes As it only acts at insensible distances, whatever tends to increase these distances, or oppose the approach of the ultimate atoms, opposes chemical union.

Extreme cohesion is thus an obstacle to chemical union, and by diminishing this cohesion, as by heat or mechanical means, we promote the combination desired. This is exemplified by the union of the metals with each other. In the solid state they do not combine: in the melted or liquid state their particles can come into intimate contact, and they form alloys. Again; as heat beyond a certain degree tends to convert all solids and liquids into vapours or gases, and thus to increase indefinitely the distances between their elements, heat, may also become a barrier to chemical union. Thus substances which may co-exist in union while cold, may be decomposed by heat, if one of their elements can be converted into vapour by increase of temperature.

Gravity again frequently interferes with affinity. Light, electricity, and galvanism are also powerful modifiers of this attraction, promoting or opposing it according to various circumstances subsequently pointed out.

I shall not enter now into more minute details regarding affinity. While we study the leading properties of the simple substances, the varieties of affinity will be insensibly learned. I proceed to offer some general remarks on the elementary bodies, and the laws by which their union is governed.

The experience of mankind, and the researches of chemists, have proved, that all the material substances with which we are acquainted are each made up of one or more elementary ingredients. Of these elements, fifty-five have been discovered and their properties studied with precision. As the letters of the alphabet compose all the words in the largest volume, so do these elements, singly or united, constitute the whole fabric of this globe. A few, four in number, exist in the form of air—some are solid—others, and the great majority, occur in the metallic state. With many of these elements or simple substances, the most inexperienced youth must be familiar in some degree. Gold, silver, iron, copper, and lead, are objects which he daily sees, and may examine. These are justly termed *simple* metals, because as far as human knowledge extends, it is impossible, from a certain weight, from a pound or grain,—for instance, of gold, or silver, or iron, or lead,—to form any substance of different properties, unless by adding some other element to the first.

Thus if we weigh a pound of lead, and melt it on a common fire, and stir the melted metal for some time in contact with the air, the metal will change into a substance of a yellow and red colour, and lose all its metallic properties. But when the mass has become cold, if we weigh it again, we find that it weighs more than a pound; and hence we must conclude, not that the metal has been decomposed, but that it has united with some other ponderable matter derived from the air itself.

The student here meets the first difficulty of the few that the science of chemistry presents. Is then the air which we breathe, that which constitutes the atmosphere around this earth,—is that air a material, a ponderable substance? A few simple experiments will supply a satisfactory answer.

If we place a glass vessel, *apparently* empty, with its mouth downwards, in a vessel containing water, and press the former deep into the liquid, we see that no water enters; its admission is resisted by the air which the vessel is thus proved to contain. The air is consequently possessed of some of the properties of matter. That it has weight, is shewn by fixing an instrument, called an air-pump, to the mouth of a glass vessel of a certain weight containing air. The action of the pump draws the air from the vessel, in the mode explained and delineated in the Appendix, and on weighing the vessel after the experiment, we find it lighter than before. It has lost air and weight together. The air is consequently a material and ponderable substance, and minute experiments shew that 100 cubic inches weigh exactly 31¾ grains.

To revert, then, to the effect produced on the lead by melting and exposing it to the air, as previously described; the weight of the metal has been augmented, the properties of the metal altered. It has hence united with some material substance contained in the air itself. The experiments subsequently described will clearly explain what takes place, and shew that the atmosphere is a compound of two simple airs or gases; that one of these, termed *oxygen* on its first discovery, forms solid compounds with the metals and with many other substances; that the other, named *nitrogen*, does not unite with the metallic bodies. The melted lead thus absorbs the oxygen of the air, and leaves its nitrogen unaffected. An *oxide* of lead (as it is termed) has been formed, from which, by appropriate means, we can expel the oxygen, and regain the metal in its original weight. It is easy, moreover, by proper instruments to act with a known weight of lead (100 grs.) on a certain bulk, say 100 cubic inches of atmospheric air; the lead absorbs 21 cubic inches of oxygen; its metallic lustre disappears, and it increases nearly seven grains in weight. The remaining air is *nitrogen*, the properties of which are very different from that of our atmosphere. In this *nitrogen*, a light will not burn; an animal cannot breathe; it does not alter lead or other metals. And lastly, if we take these 107 grs. of oxidized lead, place it in an iron vessel, and heat it in a strong fire, a part of the *oxygen* will leave the lead. Again we can collect it, and measure it, and examine its properties. It promotes energetically the burning of all kindled bodies; a hot iron plunged into it will inflame and blaze. It excites the breathing of animals, and invigorates all the functions of their system; and mixed with the gas nitrogen, it forms again the air of which our atmosphere is composed—the air in which we find the properties of either gas so blended and adapted, that the inertness of one and the stimulating powers of the other, reciprocally co-operate for the preservation of the animal and vegetable world.

In the preceding observations, the reader will find a guide to the comprehension of many apparent difficulties. They point intelligibly to the nature of the elementary bodies, they denote the mode in which the chemist unravels and demonstrates the nature of the compound substances these elements produce. They exhibit the admirable powers of the science which thus interprets many mysterious phenomena in nature; and they lead to the most pleasing anticipations of the gratification in reserve for the student as he proceeds in this method of scrutinizing the fabric, the functions, and uses of living, as well as inanimate things.

In the subjoined list we have arranged the simple substances in three classes—those which when uncombined exist as gases, or as solid substances devoid of metallic properties—and lastly, the simple metals. We also append the names of their discoverers, the date of the discovery, their abbreviated symbol, and equivalent number.

CATALOGUE OF ELEMENTARY SUBSTANCES.

CLASS 1.—*Simple Airs or Gases.*

Names.	Symbols.	Equivalents.		Authors of Discovery.	Dates of Discovery.
		O. as 100	H. as 1.		
					Christian æra.
Oxygen,	O.	100.0	8.01	Dr. Priestley, ...	1774
Hydrogen,	H.	12.5	1.00	Mr. Cavendish, ...	1766
Nitrogen,	N.	175.0	14.00	Dr. Rutherford, ...	1772
Chlorine,	Cl.	442.6	35.47	Scheele, ...	1774

CLASS 2.—*Simple Substances not Metallic.*

Names.	Symbols.	Equivalents.		Authors of Discovery.	Dates of Discovery.
		O. as 100	H. as 1.		
					Christian æra.
Carbon or the Diamond,	C.	76.0	6.08	Known to the Ancients,	
Sulphur,	S.	201.17	16.12	Ditto ditto,	
Phosphorus,	P.	392.3	31.44	Brandt,	1669
Boron,	B.	136.2	10.91	Sir Humphrey Davy,	1807
Selenium,	Se.	494.6	39.63	Berzelius,	1818
Iodine,	I.	1579.5	126.57	Courtois,	1812
Bromine,	Br.	978.3	78.39	Balard,	1826
Fluorine,	F.	233.8	18.74	Faraday and Knox,	1833

CLASS 3.—*Simple Metals.*

Names.	Symbols.	Equivalents.		Authors of Discovery.	Dates of Discovery.
		O. as 100	H. as 1.		
Gold,*	Au.	2486.0	199.21	Known to the Ancients.	Christian æra.
Silver,*	Ag.	1351.6	108.30		
Iron,*	Fe.	339.2	27.18		
Copper,*	Cu	395.7	31.71		
Mercury,*	Hg.	1265.8	101.43		
Lead,*	Pb.	1294.5	103.73		
Tin,	Sn.	735.29	58.92		
Antimony,*	Sb.	1612.9	129.24	Described by Basil Valentine in,	1490
Bismuth,*	Bi.	886.9	71.07	——by Agricola in	1530
Zinc,*	Zn.	403.2	32.31	——by Paracelsus in	16th Century.
Arsenic,*	As.	940.1	75.34	Brandt, in	1733
Cobalt,	Co.	369.0	29.57	Ditto,	
Platinum,*	Pl.	1233.5	98.84	Wood, Assay Master Jamaica,	1741
Nickel,	Ni.	369.7	29.62	Cronstedt,	1751
Manganese,	Ma.	345.9	27.72	Scheele,	1774
Tungsten,	W.	1183.0	94.80	D'Elhuyhart,	1781
Tellurium,	Te.	801.76	64.25	Müller,	1782

CLASS 3.—*Simple Metals.*— *(continued.)*

Names.	Symbols.	Equivalents.		Authors of Discovery.	Dates of Discovery.
		O. as 100	H. as 1.		
					Christian æra.
Molybdenum, ...	Mo	598.5	47.96	Hielm, ...	1782
Uranium, ...	W.	2711.4	217.26	Klaproth, ...	1789
Titanium, ...	Ti.	303.66	24.33	Gregor, ...	1791
Chromium, ...	Cr.	351.8	28.19	Vauquelin, ...	1797
Columbium, ...	Ta.	2307.4	184.90	Hatchet, ...	1802
Palladium,......	Pd.	665.9	53.36	Wollaston, ...	1803
Rhodium, ...	R	651.4	52.2		
Iridium,.........	Ir.	1233.5	98.84	Descotils and Smithson Tennant, ...	1803
Osmium, ...	Os.	1244.5	99.72	Smithson Tennant,.........	1803
Cerium,......... ...	Ce.	574.7	46.05	Hesinger and Berzelius,...	1804
Potassium, ...	K.	489.9	39.26	Sir Humphrey Davy,	1807
Sodium, ...	Na.	290.9	23.31		
Barium, ...	Ba.	856.9	68.66		
Strontium, ...	Sr.	547.3	43.85		
Calcium, ...	Ca.	256.0	20.52		
Cadmium, ...	Cd.	696.8	55.83	Stromeyer, ...	1818
Lithium, ...	L.	80 3	6.44	Arfvedson, ...	1818
Silicium,.........	Si.	277.3	22.22	Berzelius, ...	1824
Zirconium,......	Zr.	420.0	33.67		
Aluminium, ...	Al.	171.2	13.7	Wöhler, ...	1828
Glucinium, ...	G.	331.3	26.54		
Yttrium,.........	Y.	402.5	32.25		
Thorium, ...	Th	744.9	59.83	Berzelius, ...	1829
Magnesium, ...	Mg.	158.3	12.69	Bussy, ...	1829
Vanadium,.........	V.	856.9	68.96	Sefstrom, ...	1830
Lantanium, ...	La.			Mosander, ...	1839

Of these 55 substances, only 14 occur in nature in the elementary or uncombined state; namely carbon and sulphur, among the non-metallic solids;—and among the metals those to which an asterisk (*) has been affixed. Each of the remaining 41 is found associated with one or more elements of another kind. Thus hydrogen and oxygen co-exist in water, which can be entirely resolved into these gases: oxygen and nitrogen form atmospheric air. Chlorine constitutes one of the ingredients in common salt, from which it is readily extricated. Of the sources of the other elements I shall treat in another place.

With reference to the mode in which these elements combine with each other, the researches of chemists have determined the important fact, that in a multitude of instances the combining ingredients are present in a definite proportion to each other. Thus nine parts by weight of water are composed of eight of oxygen and one of hydrogen, and where oxygen and hydrogen unite in a different proportion, another and a different compound is produced. Again, several simple substances,—the metals for instance,—may combine with oxygen or other elements in more than one proportion, and the second proportion is in such cases found to bear a simple ratio to the first. Thus the metal mercury forms with oxygen two compounds or oxides,—one, which consists of mercury 202 parts, oxygen 8 parts by weight; another, composed of mercury 202, and oxygen 16,—twice the proportion in the first. Or the simple ratio in other instances is found to be that A unites with 1, 1½, 2, 2½, &c. of B. Thus one oxide of iron consists of 28 parts, or one proportion of iron, to 8 parts, or one proportion of oxygen; another oxide of iron contains 28 parts, or one proportion of iron to 12 or 1½ equivalents of oxygen. And, lastly, the relative quantities in which these bodies unite, may always be expressed by proportional numbers. Thus the metal mercury unites with two proportions of oxygen: 202*m*. 8*o*, 1st oxide: 202*m*. 16*o*, 2nd oxide. With sulphur, mercury forms two sulphurets, which chemists find to contain respectively, mercury 202, sulphur 16, 1st sulphuret; mercury 202, sulphur 32, 2nd sulphuret.—Mercury unites with chlorine in two proportions, of which the first chloride contains mercury 202, chlorine 35; the second chloride, mercury 202, chlorine 70,—twice the proportion of the first. Now oxygen and hydrogen when they form water co-exist in the ratio of 8 oxygen, to 1 hydrogen; and when oxygen unites with mercury, the first compound is mercury 202, oxygen 8; and when sulphur unites with hydrogen, its first compound is of sulphur 16 and hydrogen 1. When sulphur unites with oxygen, its first compound is sulphur 16 and oxygen 8; the same numeral thus expressing the combining proportion or equivalent of the element with whatever other element it may unite.

It would be utterly useless to multiply these examples, or to enter more minutely into the demonstration of these important laws. While the student has learned no more of the elementary bodies than their mere names, he can form no accurate idea of their mode of combination. But as he proceeds from one element to the other, he will insensibly acquire the knowledge of these laws; and on the completion of the catalogue, he will find the subject more fully discussed.

NOMENCLATURE, OR TECHNICAL TERMS.

The technical words used in the science of Chemistry are so few in number, and arranged in so simple and admirable a system, that instead of adding to the difficulties of the study, they assist the memory to a great degree.

Not quite a century, however, has elapsed since the terms used in Chemistry were so rude and arbitrary, so devoid of all arrangement or philosophical foundation, that it was almost a matter of impossibility to pursue a systematic or extended course of study on the subject. The elements that were established were named differently in different countries. In many instances every writer used a peculiar phraseology. Often, indeed, in a majority of cases, the names used were founded on some fanciful or absurd speculation. The professors of the art, too, were accustomed to throw a veil of mystery and delusion over their proceedings, to which a false terminology of course lent ample assistance. Had this state of things continued, Chemistry to this day would have remained almost a useless pursuit. The arts which now owe their excellence to its progress, would have continued in their comparatively rude condition, and many invaluable remedies would have been altogether undiscovered. The cause of this is manifest. The progress of knowledge in Chemistry could not have been diffused until an intelligible and standard language was employed to express it—a language independent of fancy, uniform for all nations, and containing in itself the basis for the formation of any new terms which subsequent discovery might demand.

To the labours of four great French chemists, Lavoisier, Berthollet, Guyton Morveau, and Fourcroy, the world is indebted for the first thorough reform of the confusion I have described, and for the formation of a system of terms of admirable simplicity and practical utility. These terms are now universally adopted, with the necessary additions and modifications which the discoveries daily occurring require.

The principles these philosophers followed are readily understood. The known elementary or simple substances, and many of the established and well-known compounds, were allowed to hold the names by which they were generally known.

Sulphur, for instance, and phosphorus, and the metals known to the ancients, continued to retain their original names. New elements as discovered were named according to their most striking property. Thus the gas Hydrogen was called so from two Greek words signifying the generation of water, as it was found that this gas was one of the ingredients of that fluid. Iodine is so termed from its giving out a violet coloured vapour when heated. Chlorine received its name from its green colour at ordinary temperatures. The newly discovered metals Potassium, Sodium, Aluminium, &c. derive their names from potash, soda, and alum, from which they are prepared.

As oxygen gas enters into a vast multitude of compounds, it became a matter of great consequence to embrace these in some clear and distinguishing terms. On examination a great number were found to possess *acid* properties, and were accordingly called *acids;* others destitute of these properties, but still containing oxygen, were called *oxides.* The *acid* was named by adding the letters *ic* to the name of the simple substance or *base*; thus, sulphur and oxygen formed sulphuric acid. But often oxygen formed two or more acids with a base, by uniting with it in one, two, or three proportions; thus sulphur formed two known distinct acids, one containing less oxygen than the other. The one with most oxygen was called sulphuric—with the least, sulphurous acid. Thus there are nitrous and nitric acids, phosphorous and phosphoric acids, iodous and iodic acids, and many other examples.

The compounds of the non-metallic simple substances, carbon, phosphorus, and sulphur with each other, or with the metals, were named by adding the syllables *ide* or *uret* to the non-metallic elements. Thus we have *sulphuret, carburet, phosphuret, chloride,* and *iodide,* of lead, iron, &c. Again, oxygen, carbon, sulphur, &c. were observed to be present in certain compounds in different quantities; and as the proportions are observed in most instances to have a determined arithmetical relation to each other, they were named by adding a corresponding Greek or Latin numeral to the substance, the amount of which varied.

Three Greek and one or two Latin numerals are nearly all the student requires to learn to enable him to understand this, perhaps the most essential department of chemical nomenclature. These are—

Protos, 1st.

Deutos, 2nd—or *bis,* Latin numeral.

Tritos, 3rd—or *ter,* Latin numeral.

Thus, Protoxide. Deutoxide or Binoxide. Tritoxide.

Or occasionally the greatest or highest amount of oxidation was expressed by the syllable Per, or most; *Peroxide.* Where one and a half proportion existed, the Latin word *Sesqui* was employed.

Thus there are—

Proto-oxides,	Deutoxides or Bin-oxides,	Sesqui-oxides,	Per-oxides,
Proto-sulphurets,	Bi-sulphurets,	Sesqui-sulphurets,	Per-suphurets,
Proto-carburets,	Bi-carburets,	Sesqui-carburets,	Per-carburets,
Proto-chlorides,	Bi-chlorides,	Sesqui-chlorides,	Per-chlorides,
Proto-iodides or iodurets,	Bin-iodides, or iodurets,	Sesqui-iodides, or iodurets,	Per-iodides, or iodurets.

I have now given a sufficient key to our ensuing study of the simple gases and non-metallic substances. The nomenclature of salts, or of compounds of acids and alkalies or other salifiable bases, would be attended with much difficulty if now attempted, but will be readily acquired as we obtain the knowledge of the materials of which these compounds are formed.

We shall now proceed to the simple *gases*. This term is used to denote an aëriform or air-like fluid, which is permanently elastic, or retains the aëriform as its natural state under ordinary circumstances; it thus differs from a vapour which though an aëriform fluid and elastic-like steam, is but the product of a denser liquid existing as a liquid in its ordinary condition.

SECTION II.

THE SIMPLE GASES.

OXYGEN GAS—ITS SOURCES—MODE OF PREPARATION, AND PROPERTIES.

The element oxygen is by far the most important of all simple substances. It constitutes one-fifth of the atmosphere we breathe, and on its presence in due proportion is our respiration altogether dependent. It forms eight-ninths of the water of the globe—and in the solid state, in union with the solid elements, especially the metals, it exists in inconceivable quantities. Associated again with hydrogen, nitrogen, and carbon, it forms a large proportion of the fabric of all animals and plants.

From all these sources we may, by various processes, obtain this gas in its uncombined or elementary state. The simplest and the most intelligible, though not the easiest process is the one I shall first describe.

If 202 grains of the metal mercury be placed in a glass vessel of the shape drawn in *Plate 1. fig. 1,* and the vessel kept heated on sand for several days, the mercury loses its metallic appearance, and changes to a scaly mass of a brilliant red colour. When the change is accomplished, if we weigh the red substance we find its weight to be 218 grains. This substance was called *red precipitate* by the older chemists, and on analysis or chemical examination it is found to be composed of mercury 202, oxygen 16 parts by weight. There are other and easier processes by which this red oxide of mercury is manufactured in large quantities, as I shall subsequently explain, but that I have now described is the least complex, and consequently the most intelligible to the commencing student.

To obtain oxygen from this red oxide of mercury, we should provide ourselves with the following cheap articles of apparatus, which can be made or bought in every bazar, and which will answer for experiments on many other gases.

First, an iron tube six inches long, cut from the breech end of a gun-barrel. To the open end of this tube should be adjusted a close fitting iron stopper, with a round hole to receive a pipe two or three feet long, one-third inch in diameter, made of sheet copper, and the edges joined air-tight by brass solder. If the copper sheet be heated to redness and suddenly cooled in water, the tube will be quite flexible and soft. This little apparatus is termed an iron retort, and is shewn in *fig.* 2.

The next essential instrument is a water vessel so constructed that bottles or jars can be filled and inverted and supported in it, as shewn in *fig.* 3. The common earthen vessels of the bazar answer extremely well. For supporting the bottles a piece of thick sheet iron may be bent to the shape shewn in the figure, and placed like a stool in the earthen vessel. A few wide-mouthed phial bottles, and some pieces of window glass, two or three inches square, complete the apparatus.

Before proceeding to make oxygen or any other gas, the pupil should practise with common air the mode of transferring gases from one vessel to another. Let him fill a bottle with water and place a piece of window glass on its mouth and invert the bottle; no water will fall out as long as the glass is applied: let him now place the full bottle on the little iron frame in the trough, the mouth downwards; the trough being filled with water to half an inch above the iron stand. He may then remove the glass plate, and the bottle will continue full of water. Let him next place the open mouth of a bottle containing air about an inch under the surface of the water in the trough, and bringing the bottles towards each other, one in each hand, and inclining the mouth of the bottle full of air gradually below the mouth of the bottle of water, the air will pass in large bubbles into the water vessel. By practising this simple manipulation for a few minutes, the pupil will at once learn how to manage the transference of gases in water.

To return now to the process for preparing oxygen. Place 218 grains by weight of the red oxide of mercury in the iron retort; adjust the stopper and tube, and close any interstices with a little softened clay. Place the retort in a charcoal-fire, in one of the earthen chafing pans of the bazar, and the mouth of the copper tube under a little hole drilled in the iron stand in the trough; over this hole place a small bottle, mouth downwards, and full of water: bubbles of air will soon issue from the tube and ascend in the bottle.

The bottle first used should be a small one, about the size of the iron tube, or slightly larger. The air received in this, being merely the common air originally contained in the retort, and now expelled by the heat, need not be examined.

The bubbles continuing to issue from the conducting pipe are to be received in a second bottle, or more conveniently in a series of small phials, provided with corks to be introduced when each phial is filled with gas. Using the proportions above specified of the red oxide of mercury, the result of the experiment will be the collection of about 50 cubic inches of gas, and there will remain in the retort 200 grs. of mercury in the metallic state.*

The phial should next be corked, while under water, with the mouths downwards, and removed from the trough.

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* Directions for ascertaining and marking the cubic contents of bottles are given in the Appendix.

As we look at the phials containing the gas thus prepared, we perceive no difference between their contents and common air. Like common air this gas is transparent and colourless, and destitute of taste or smell. But a few experiments soon shew that a remarkable difference exists between them.

If we take a common match or splinter of wood, light it, and blow out the flame, so that a mere point of the wood remains red hot, uncork one of the phials and introduce the match; it will be instantaneously rekindled, and will burn with great splendour, until all the gas is consumed.

Or further, if we take a thin iron wire, twist a little thread round one of its ends, and dip the thread in melted sulphur, and if we light the iron wire match thus prepared, and introduce it into a large phial of the gas, the iron itself will take fire, and send off showers of brilliant sparks until all the oxygen is consumed.

In the first experiment the *carbon* which constitutes the basis of wood, unites with the oxygen to form *carbonic acid*, a compound consisting of carbon one proportion, oxygen two proportions. In the second experiment a protoxide of iron is produced containing one equivalent of oxygen, and one of the metal iron—of these compounds we will treat minutely in another place.

The process now described is, however, comparatively expensive, as there are many other oxides, much cheaper than peroxide of mercury, from which this gas may be obtained. Thus there exists in great abundance in many countries a mineral peroxide of the metal manganese, composed of manganese 27 parts or one equivalent, oxygen 16, or two equivalents. This peroxide is a black substance; it occurs in mines in many parts of Europe and Asia, and has recently been found in large quantities near Ajmeer in upper India. Under the head of manganese I shall treat of this mineral more precisely. When heated in the gun-barrel retort just described, it loses half a proportion, or four parts by weight of its oxygen, and becomes a sesquioxide which cannot be decomposed by increase of temperature. Thus the oxides of manganese are—

	Manganese.	*Oxygen.*	
Protoxide,	27,7. or 1 equivalent,	8 or 1 eq.	= 35,7.
Sesquioxide,	27,7. or 1 eq. ———,	12 or 1½ eq.	= 39,7.
Peroxide,	27,7. or 1 eq. ———,	16 or 2 eq.	= 43,7.

and consequently when 43 parts of the Peroxide are heated to redness, four parts by weight of oxygen are given off, and 39,7. parts of the Sesquioxide remain in the retort.

When neither peroxide of mercury nor of manganese can be procured, oxygen gas may still be obtained from saltpetre or nitre. When 100 parts of this salt are melted at a high temperature, about eight parts by weight of oxygen are evolved; several other gases are also obtained as the nitre fuses, but as the oxygen comes first we can collect it separately. I shall not attempt to explain here the decomposition which occurs; the pupil will find it described under the head of "Nitrate of Potash," in another section. But I would recommend him not to look for it until he meets it as he proceeds through the volume.

There are many other processes by which this gas may be obtained, which it would be useless to enumerate here; the more advanced student will find them explained under the heads of water, manganese, chlorate of potash, and lead.

In preparing oxygen from saltpetre, the gun-barrel retort should not be used, owing to the bulk of the material, and for other reasons also. The melted salt is liable to be projected into the tube, where it would immediately concrete, and the gas thus pent up would probably occasion a dangerous explosion. The vessel employed should be a very large iron bottle if procurable, or a large green glass bottle may be provided with a pipe and stopper, and heated in sand to the necessary temperature for the extrication of the gas. Where large quantities of the gas are to be collected, vessels called gasometers are used. Of these there are many varieties, of which I shall describe three which combine all the good qualities of the rest, with this great advantage—that they can be constructed cheaply in every bazar.

The first of these vessels is the invention of Mr. Pepys. It is made of tinned sheet-iron, or copper, japanned or painted inside and outside. The *figure No.* 4 represents Mr. Pepys's gas-holder, the most convenient form of this apparatus hitherto contrived. A is the body of the gas-holder, intended to contain the gas; B a trough supported on three pillars, resting on A; *c* a flexible tube conveying gas through an aperture that permits the water to escape as it enters; *b* a stop-cock connected with a flexible tube through which the gas may be propelled after it has been collected; *e* another stop-cock connected with a tube open at both ends and passing between A and B, through which the gas may be made to pass (when *b* is shut) into a jar full of water, placed in the trough B. A tube (*a*) open at both ends, is continued from the trough to the bottom of A; *d d* is a glass tube open at both ends, and cemented into the upper and lower part of A, to indicate the quantity of gas inside, the fluid in the tube being always at the same level with the fluid in the large vessel. When the gas-holder is to be used, the aperture at *c* is closed by a plug made to screw upon it; and water being poured into B it passes down through *a* into the body of the gas-holder, the atmospheric air being forced through *b* (which is also opened) as the water rises in A. All the stop-cocks are shut when the gas-holder is full of water, and the plug which closes the aperture at *c* being unscrewed, the tube which conveys the gas may be introduced. The gas will rise through the water, as represented in the figure, while the latter flows out in a continued stream as long as any gas enters; great care must be taken not to open any of the stop-cocks while the plug at *c* is unscrewed, as the water would then rush out with great violence, and the gas-holder be filled with atmospheric air in a few seconds. When the gas-holder is full the tube is withdrawn, and the plug screwed on; the trough *b* is then filled with water, and on opening the stop-cock in the tube *a*, the water descends and presses upon the gas; but none escapes unless the stop-cocks at *b* or *a* are opened, through either of which the gas may be propelled by opening the one and shutting the other.

The stop-cocks alluded to are made of brass, and are very easily constructed according to the section and drawings given in *fig.* 5. The glass tube mentioned in the description may be left out without material inconvenience.

The second gas-holder is the invention of Dr. Hope, the Professor of Chemistry in Edinburgh, and in point of economy and facility of construction is quite unrivalled. The apparatus is thus described by Dr. Reid. (*See fig.* 6.)

"It consists of a large oil of vitriol or turpentine bottle, with a brass cap cemented to the mouth, in which two tubes with stop-cocks are fitted, water being introduced and forced out again when necessary by one, and gas by the other. In the figure, it is represented in connection with the extremity of a bent gun-barrel, fixed in an iron retort in which oxygen is prepared from the peroxide of manganese by heating it in a furnace. It is obvious that a large bottle of this kind could scarcely be moved when full of water without being broken, unless properly supported, and nothing does better for this than a tub made to fit the bottle, covering the bottom for the depth of an inch or two with sawdust, and packing the space between the bottle and the sides with the same material. This will allow it to be moved easily from one place to another, and it has not been represented in this manner in the figure merely that the arrangement of the tubes connected with it may be seen more distinctly.

To explain the method of using it, I shall now describe the manner in which it is filled with oxygen gas. After filling it with water, a bent tube is to be connected with the gun-barrel by a flexible leaden tube, about two or three feet in length, though represented much smaller in proportion to the size of the rest of the apparatus in the figure; but no gas is to be allowed to pass into it unless it is sufficiently pure, the stop-cock at the extremity of the gun-barrel being kept shut, while the other one is to be opened, and the gas that is disengaged at first collected by means of a bent tube fitted to it, in small bottles over a pneumatic trough, so that its state of purity may be easily ascertained. When it is thought proper to commence collecting it, this stop-cock is to be shut and the other opened, so that the oxygen will now pass on to the gasometer, entering by one of the first mentioned tubes. Here it will press upon the surface of the water, which will be forced up through the tube seen in the interior of the bottle, continuous with the second stop-cock attached directly to the cap, and another bent tube being then placed over it, a syphon is formed, through which the water will continue to flow as long as any gas is disen-

gaged; and using a large quantity of materials at a time, several bottles may be filled successively in this manner without undoing any part of the apparatus, except the leaden pipe that connects them directly with the gun-barrel. One bottle may be detached and replaced by another in a few seconds when every thing is properly adjusted; and if a longer time should be required, a few jars of oxygen may be collected from the tube attached to the stop-cock fixed to the upper part of the gun-barrel, or that tube may be adjusted to the second bottle gasometer while the first one is filling. The stop-cocks attached to the brass cap of these gasometers must be shut, as the tubes connected with them are detached.

Again, the next *figure* (7) shows the method in which the gas is transferred from a gasometer of this kind when required for use. The syphon being detached, a tin funnel is placed above the stop-cock to which it was previously fixed, and it is evident, that on pouring water into it and opening the stop-cocks, it will descend through the tube in the interior of the bottle, and force the oxygen out at the other stop-cock by which it had entered, which opens immediately below the cap itself; by connecting a flexible tube, accordingly, with this stop-cock, and pouring water into the funnel, the gas may be easily transferred to other vessels. It is in the same manner, also, that the air is expelled, and the gasometer filled with water before connecting it with the oxygen gas apparatus."

Griffin's stone-ware gasometer, is simple—a closed jar of one to two gallons capacity is provided with two openings at top and one below at the side, as shewn in *fig.* 8. A piece of half-inch leaden or copper pipe descends from the central upper opening, which is attached to a stop-cock, and on this a varnished tin plate funnel *(b)* can be screwed at pleasure. To the lateral upper opening a similar stop-cock is attached, to which a delivering tube may be fixed; the lowermost orifice may be closed by a cork. The use of this instrument is the same as that of Pepys.

A common stone jar, such as those found in the bazars, may be adjusted readily, so as to afford a substitute for this apparatus, by drilling an aperture above, and another at the side, and cementing into each a corresponding tin plate or copper tube varnished, for the attachment of the cocks or insertion of corks. A figure is given of a vessel so fitted. The tube below should be inclined upwards, as shewn in *fig.* 9, and run internally about an inch and a half.

Before we can proceed further with our study of oxygen gas, we must examine the leading properties of some other simple elements.

SECTION III.

HYDROGEN GAS AND WATER, *(the Protoxide of Hydrogen.)*

The admirable researches of the chemists who lived towards the close of the last century, established the deeply interesting fact that water—that fluid with which we are so familiar, on which our existence is so dependent—which the vague ideas even of our immediate forefathers regarded as pre-eminently an element,—is in truth a compound body—a compound in which two airs or gases united by chemical attraction assume the liquid state,' from which they can again be recalled by the chemist into their original gaseous condition.

The experimental proof is easily and quickly procured. If a piece of iron be heated red hot, and water dropped on it, a black substance is formed wherever the water touches; the iron increases in weight, and if we examine the black substance we find it identical with the product obtained by burning iron in oxygen gas—it is protoxide of iron, the oxygen having been derived from the water. Again, if we weigh a piece of gun-barrel accurately, and adjust to one end the copper tube of the retort previously described, and to the other a stopper and funnel by means of which a little water may be introduced into the barrel; let this be now heated to redness, and a few drops of water poured in; the water is forthwith decomposed, the oxygen unites with the iron; the other constituent gas, hydrogen, is set free in large quantities, rushes through the copper tube, and may be collected with ease by the water-trough and bottles already described.

This experiment has been made with the utmost minuteness. Nine grains by weight of water were conducted in vapour through a glass tube heated to redness, and containing 28 grains of pure iron. The iron increased eight grains in weight, and was changed into the *protoxide*, while one grain by weight of the gas hydrogen was evolved, collected, and examined.

Its properties are extremely interesting. It is a highly inflammable gas, but does not support the combustion of other bodies—thus differing from oxygen, which cannot be made to burn itself, although it promotes the burning of other bodies. Thus, when we plunge a half extinguished taper into oxygen gas, the taper is rekindled; if we introduce a fully lighted taper into hydrogen, the hydrogen takes fire, and burns with a pale blue flame, but the taper is extinguished as quickly as if it were immersed in water.

Again, hydrogen differs from oxygen in its effects on animal life. A bird or any other living thing plunged into hydrogen dies very speedily. Further, if a glass flask be exhausted of air by the air-pump and weighed, and then 100 cubic inches of oxygen introduced, the weight of that quantity of gas is found by the increase of weight of the flask to be 34.19 grains. Repeating this experiment with hydrogen, the curious result was obtained that 100 cubic inches of hydrogen weigh only 2.137 grs. Now atmospheric air, similarly examined, weighs 31.011 grs. Thus hydrogen gas is sixteen times lighter than oxygen, and *fifteen times lighter than the air we breathe.* It is, in truth, the lightest of all known things. In an atmosphere of hydrogen, the lightest feather falls like a stone in the open air; and when we enclose large volumes of this gas in light capacious reservoirs of varnished silk, the balloon, thus floated, rises through our atmosphere, and swims on it as a ship on the surface of water, upbearing with it the adventurous æronaut miles above the habitations of man, to regions whither the vulture and the eagle in vain attempt to soar.

Nor are these the only peculiarities of this remarkable element. There is a metal called *platinum,* which by a peculiar process (explained under that head) can be brought into a porous or spongy state. If a small fragment of this sponge be exposed to a jet of hydrogen gas in contact with atmospheric air, the metal instantaneously becomes red hot, and the gas itself is inflamed. We avail ourselves of this extraordinary property, in the construction of lamps, which afford us instantaneous fire.

But it is not alone from the analytical experiments above described that the chemist infers the composition of water. By a series of different facts and researches he arrives at the knowledge of this important truth. Of these the most conclusive and instructive is the effect produced on water by electrical currents, excited by the apparatus termed the Galvanic Battery. The construction and chemical uses of this apparatus are described in a separate article in the Appendix.

If a series of several plates or cylinders of copper and zinc be arranged, so that a plate of copper and one of zinc are in contact with each other in separate cells, by pouring a mixture of water and acid (100 parts by measure of water, 2 sulphuric and 1 nitric acid) into the trough, the plates become highly electric;—and if we bring a thick wire from each end of the trough, and approach these wires to each other, certain curious and interesting phenomena are observed. If we bring the wires suddenly in contact, or quickly withdraw them from each other, a spark passes. If we touch the wires with our moistened fingers, we experience a sudden sensation of having received a shock or blow; and, lastly, if we dip these wires in water, the water is decomposed. From each wire (if of platinum or gold) there arises a copious stream of minute gaseous bubbles. By adjusting tubes or jars above each wire, as shewn in *fig.* 10, oxygen collects in one and hydrogen in the other. The properties of these gases are so peculiar, that no difficulty occurs in their perfect identification.

But the series of proofs does not terminate here. When the galvanic battery is withdrawn, we find that the hydrogen gas obtained is twice the bulk or measure of the oxygen; and were we to perform the experiment one thousand times, the same proportionate result would be invariably obtained. The inference must obviously be drawn, that these are the exact proportions of the gases by measure required to constitute water; and experiment proves the justice of the conclusion. For when we take two measures of hydrogen and one of oxygen, mix these together in a jar, and then introduce this mixture into a perfectly dry glass vessel exhausted of air,* by applying a taper, or introducing a piece of platinum sponge, or causing an electric spark to pass through the vessel, the gases immediately combine with an explosion, and on the sides of the vessel we see the water which the gases have formed trickling down in drops like condensed dew.

This experiment, the chemical recomposition of water, or *synthesis* as it is scientifically termed, has been repeated on an immense scale. Large quantities of oxygen and hydrogen were prepared, in the proportion of one measure of the former to two of the latter. The bulk of each gas, and consequently its weight being known, it was calculated how much water their combination should yield; and true to calculation, the water formed coincided exactly with the predicted results.

Again, when equal parts of oxygen and hydrogen are employed in the exploding apparatus, one measure of oxygen remains unaffected by the explosion; or if three measures of hydrogen are used to one of oxygen, one measure of hydrogen remains. Thus the chain of evidence is complete to its minutest link, and one of the most wonderful of all natural truths revealed by the sagacity of man.

Having thus explained the leading facts connected with the *analysis* and *synthesis* of water, the pupil will experience but little difficulty in comprehending the usual processes for the preparation of hydrogen gas.

There is an acid of great strength composed of sulphur and oxygen, and called, the sulphuric acid, or oil of vitriol. This acid has a powerful chemical attraction or affinity for various metallic oxides, with which it forms salts. Thus, if oxide of zinc or oxide of iron be added in certain proportion to sulphuric acid, a compound called sulphate of zinc or iron is pro-

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* *Cavendish's Eudiometer*. Instead of the electric spark, which we can very seldom obtain in Bengal, a loop of platinum wire can be always ignited by a small battery, and affords an equally beautiful and conclusive experiment.

duced. These compounds are transparent crystals, free from all acidity, soluble in water, and in common with a multitude of similar substances, are termed *neutral salts.*

Now if metallic zinc or iron, and water, and sulphuric acid, be mixed together in a bottle, in the proportion of one part acid to four water, violent effervescence immediately takes place. The water is decomposed; its oxygen unites with the zinc or iron to form an oxide which associates with the sulphuric acid to form sulphate of zinc or of iron, and the hydrogen of the water is set free in the gaseous state.

It is very easy with a common quart bottle, a good cork, and a foot or two of flexible copper, lead, or silken tube, to collect hydrogen gas in abundance with the water-trough and common bottles already described. If a bladder with a tube or nozzle with a fine aperture be filled with this gas, on applying a light the gas inflames and burns tranquilly with a pale blue flame. If a jet of the gas be directed on a piece of platinum sponge, the metal will become red hot, and the gas be inflamed. A small balloon of light and varnished paper filled with this gas ascends rapidly in the air,* or soap bubbles may be inflated from the bowl of a pipe, and these will ascend also. By mixing two proportions of hydrogen and one of oxygen in a strong bottle and applying a lighted match, the gases will explode with a loud report—or by mixing two measures of hydrogen with five of atmospheric air, a similar detonation will ensue, because five measures of air contain the one measure of oxygen which the hydrogen requires. In consequence of the great levity of the gas, when we wish to shew by experiment that, though combustible itself, it does not support the burning of other bodies, the proper mode is to lift the jar or bottle of gas from the water-trough, on a glass plate, with its mouth still downwards. Bring the jar near a lighted candle, and withdrawing the glass plate, depress the mouth of the jar gently over the

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* The gas must be dried by being passed through a tube 12 inches long ½ an inch in diameter, placed horizontally, and filled with fragments of muriate of lime—the bag of paper at least a foot in diameter, and quite dry.

flame; the gas will take fire and the candle be extinguished, and by alternately rising and depressing the jar, the experiment may be repeatedly performed, the taper being re-inflamed and extinguished several times.

The heat produced during the combustion of hydrogen gas in oxygen is the most intense that can be obtained by artificial means. When properly directed, the most infusible substances, iron, platinum, flint, &c. melt or disappear before it; and when some of the earths, such as lime and magnesia, are thus heated, the light evolved is as intolerable to the naked eye as the direct rays of the sun. In the instrument first contrived for these experiments, the gases were mixed and condensed into the same vessel:—a proceeding of the utmost danger, owing to the extremely explosive nature of the compound. A contrivance recently invented by Mr. Hemming of London obviates, however, this objection. The gases are made to issue through a brass cylinder about six inches long, filled with very fine brass wire. A pointed rod of metal is forcibly driven into the centre of the bundle of wires, the interstices between which constitute, as it were, a series of very minute tubes, which are found effectually to prevent the passage of flame and the occurrence of explosion.

A substitute for these expensive instruments, and one quite free from danger, was invented by Mr. Gurney, and is well adapted for district schools in India. Its construction is shewn in *fig.* 11. It consists of two bladders, one removable at pleasure. The central one can be pressed on by a light wooden frame guided by four brass rods. The gases issue through a piece of brass tube filled with wire, according to Mr. Hemming's contrivance, and the flame may be made to play on pieces of metal, lime, &c. supported on pumice stone. Some very instructive experiments may thus be exhibited without the least danger. Indeed, the demonstration may be most appropriately closed, by removing the brass tube and exploding the apparatus. The bladder is blown to pieces, and the light frame dislocated, but no mischief can possibly be done.

The physical properties of water, and its relation to heat, cannot be entered upon consistently with the limits of this volume. The chemical nature and habits of the liquid are what we must restrict ourselves to at present.

Water, or the protoxide of hydrogen, is in its pure state a transparent, colourless, fluid, which boils at the temperature of 212° of Fahrenheit's thermometer,* and freezes at 32° of the same scale. One cubic inch, under ordinary circumstances, weighs 252½ grains, and in estimating the comparative weights of the same bulk of different liquids and solids, water is considered the standard.† Owing to the nature of its elements, and the powerful affinities it itself possesses, water is one of the most universal agents in chemical changes and decompositions. It combines directly with many other bodies, and sometimes in a definite proportion—thus 28 parts of fresh burnt lime, when slaked or mixed with water, combine with and solidify nine parts or one equivalent of this liquid; and 76 parts of the earth baryta combine with nine, or one eq. of water, and the resulting solid may be heated to bright redness, and its water is not expelled. These and similar definite compounds are named *Hydrates.* But when water combines in an indefinite proportion, the word "*Solution*" is employed. Thus we speak of a solution of sugar, starch, &c.

The water of rivers, wells, and tanks is rendered impure by various saline, earthy, and organic matters, derived from the soil or from accidental sources. When collected in clean vessels during a tropical shower, it contains no fixed impurities, but is still impregnated with air. It has been remarked, too, that the air contained in water is richer in oxygen than the air of our atmosphere. By the process called *distillation,* all natural waters may be rendered pure. This operation con-

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* See Appendix, Article *Thermometer.*

† See Appendix, Article *Specific Gravity.*

sists in boiling the water in one vessel and condensing the steam in another, the condensed vapour being water in its purest state.

As we proceed with our description, we shall find that water absorbs many of the gaseous compounds, and gives these out again altogether unchanged.

As well as the protoxide of hydrogen (water) chemists are acquainted with another compound of oxygen and hydrogen, the Peroxide, in which one part by weight of hydrogen is united with sixteen parts of oxygen. As it would be next to impossible to prepare this compound in India, and since its properties are rather a subject of curiosity than of practically useful study, I shall not describe it more minutely here.

There are still many points connected with the history of hydrogen gas, the examination of which we must postpone until we have touched on the properties of nitrogen, carbon, and their compounds.

SECTION IV.

NITROGEN AND ITS OXIDES.

The experimental facts related in a preceding chapter, shew that the air of our atmosphere contains a considerable quantity of oxygen gas. As there are many substances familiar to the chemist which possess a great affinity for oxygen, we can without difficulty absorb from a given volume of air, all the oxygen it contains, and the residue is *nitrogen*, the subject of this section.

Any of the simple substances having a great affinity for oxygen may be employed for this purpose. If we introduce, for example, a mixture of sulphur and iron into a vessel containing 100 cubic inches of atmospheric air, 21 cubic inches of oxygen will disappear and form sulphate of iron ; and 79 inches and a fraction of a different gaseous fluid will remain in the jar.

Or, if instead of sulphur and iron, we use hydrogen gas in the proportion of two parts hydrogen to five of air, and introduce a piece of platinum sponge, or pass an electric spark or ignite a wire in the mixture, explosion ensues, the hydrogen forms water with the oxygen of the air, and leaves as before, 79 measures of residual gas. Potassium, mercury, phosphorus, carbon in various forms—in short, a variety of other substances, simple as well as compound, may be employed with the same result. All the oxygen disappears from the examined air.*

The remaining gas is termed nitrogen, because it enters largely into the composition of nitre or saltpetre. Other names have been frequently applied to it; among the rest *azote* from the Greek α without, and ζωή, life, because it does not support the respiration of animals.

To prepare nitrogen for experiment, a very simple process is to make a paste of equal parts of sulphur and iron filings with water. Introduce the mixture into a stoppered bottle and invert it in the water-bath—agitate it from time to time, and in twenty-four hours all the oxygen will be absorbed, leaving the nitrogen behind. The nitrogen may now be transferred into other vessels for examination.

Pure nitrogen is a colourless gas (symbol, N.) Sp. gr. 0,976, devoid of smell or taste. It does not support combustion. An adult animal immersed in it perishes very quickly. It is not inflammable; 100 cubic inches weigh $30\frac{1}{6}$ grains. It is not soluble in water, and hence may be collected and experimented on, over that liquid.

When nitrogen gas enters into combination with oxygen, hydrogen, &c. and many other substances, it forms several definite compounds, in which nitrogen always bears the proportion of 14 parts by weight on the oxygen, 175° on the hydrogen scale. Thus with oxygen, nitrogen forms five different substances, in which the following exact ratio is found to exist:—

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* See a beautiful process under the head of *Nitrous Oxide.*

		BY VOLUME.		BY WEIGHT.	
		Nitrogen.	*Oxygen.*	*Nitrogen.*	*Oxygen.*
Nitrous oxide, ...	NO_1,	100	50	14	8
Nitric oxide, ...	NO_2,	100	100	14	16
Hypo-nitrous acid,	NO_3,	100	150	14	24
Nitrous acid, ...	NO_4,	100	200	14	32
Nitric acid, ...	NO_5,	100	254	14	40

Besides these compounds, 79 measures of nitrogen, and 20.79 to 20.08 oxygen, mechanically mixed with each other, so that neither the secondary physical properties, nor the chemical habits of the gases are altered in any degree, form the air surrounding this globe. I shall describe the definite series first; for a knowledge of these bodies will materially facilitate our comprehension of various facts connected with the phenomena of the atmosphere.

PROTOXIDE OF NITROGEN, OR THE LAUGHING GAS.

This singular and interesting gas was discovered by Priestley. It is most easily prepared from a salt called the nitrate ammonia, the mode of preparation of which is given under the head of the Ammoniacal Salts.

When this nitrate of ammonia is exposed to heat, it fuses, and is totally changed into water and nitrous oxide gas. The nature of the decomposition will be readily understood by comparing the composition of nitrate of ammonia with the products it affords. These, leaving out fractions, are as follows:—

BEFORE DECOMPOSITION.		AFTER DECOMPOSITION.	
Nitric acid.	*Ammonia.*	*Water.*	*Nitrous oxide.*
Nitrogen 14 or 1 eq.	Nitrogen 14 or 1 eq.	Hydrogen 3 or 3 eq.	Nitrogen 28 or 2 eq.
Oxygen 40 or 5 eq.	Hydrogen 3 or 3 eq.	Oxygen 24 or 3 eq.	Oxygen 16 or 2 eq.
54	17	27	44

Thus the hydrogen of the ammonia takes exactly as much oxygen as is sufficient for forming water, and the residual oxygen converts the nitrogen both of the ammonia and the nitric acid into the nitrous oxide.

One pound of nitrate of ammonia will yield about five cubic feet of this gas. The salt broken into small pieces is introduced into a large glass retort, and heated by a lamp or pan of charcoal. The salt melts and boils, and the decomposition continues until the salt totally disappears. The gas must be collected in gasometers filled with salt water, because cold fresh water condenses the steam which issues with the gas, and would consequently rush back into and break the retort.* Cold water also absorbs much of the gas. With warm water it is difficult and troublesome to manage the process.

The nitrous oxide is a colourless gas, of a faint but agreeable smell, and sweet taste. It is not inflammable, but it supports the combination of other bodies so energetically, that several of the experiments performed with oxygen, may be repeated with this fluid. With an equal bulk of hydrogen it explodes violently when inflamed, water being formed and nitrogen set free. And it is remarkable that the residual nitrogen is of the same bulk as the nitrous oxide first employed, shewing that 100 measures of this gas contain 100 of nitrogen and 50 of oxygen, condensed by their union into 100 measures.—100 cubic inches of this gas weigh by experiment 47 grains and a fraction, the number which a calculation of the weights of its constituent parts, would lead us to expect,—Sp. gr. compared with air, 1.527.

But the most remarkable property of this gas is the singular effect it produces when inhaled into the lungs. The experiment may be made with perfect safety, and will generally be followed by results so extraordinary that their occurrence could scarcely be credited, had it not become one of public exhibition.

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* Excellent green glass quart retorts are made in the Machhuyá Bazar, Calcutta, for six annas each.

Sir Humphrey Davy, the discoverer of these strange phenomena, thus describes one of his first trials with the gas.

"Having previously closed my nostrils and exhausted my lungs, I breathed four quarts of nitrous oxide from and into a silk bag. The first feelings were similar to those produced in the last experiment, but in less than half a minute, the respiration being continued, they diminished gradually, and were succeeded by a highly pleasurable thrilling, particularly in the chest and the extremities. The objects around me became dazzling, and my hearing, more acute. Towards the last respiration the thrilling increased, the sense of muscular power became greater, and at last an irresistible propensity to action was indulged in. I recollect but indistinctly what followed; I know that my motions were varied and violent. In ten minutes I had recovered my natural state of mind. The thrilling in the extremities continued longer than the other sensations. This experiment was made in the morning; no languor or exhaustion was consequent, my feelings through the day were as usual, and I passed the night in undisturbed repose."

In giving an account of another experiment with this gas, Sir Humphrey thus describes his feelings: "Immediately after my return from a long journey, being fatigued, I respired nine quarts of nitrous oxide, having been precisely thirty-three days without breathing any. The feelings were different from those I had experienced on former experiments. After the first six or seven respirations, I gradually began to lose the perception of external things, and a vivid and intense recollection of some former experiments passed through my mind, so that I called out, 'What an annoying concatenation of ideas!'"

Further experiments made by the same illustrious chemist were attended by still more remarkable results. He was shut up in an air-tight breathing-box, having a capacity of about nine and a half cubic feet, and he allowed himself to be habituated to the excitement of the gas, which was gradually introduced. After having undergone this operation for an hour and a quarter, during which eighty quarts of gas were thrown in, he came out of the box and began to respire twenty quarts of unmingled nitrous oxide. "A thrilling," says he, "extending from the chest to the extremities, was almost immediately produced. I felt a sense of tangible extension, highly pleasurable in every kind; my visible impressions were dazzling and apparently magnified; I heard distinctly every sound in the room, and was perfectly aware of my situation. By degrees, as the pleasurable sensation increased, I lost all connexion with external things; trains of vivid visible images rapidly passed through my mind, and were connected with words in such a manner as to produce perceptions perfectly novel. I existed in a world of newly connected and newly modified ideas. When I was awakened from this same delirious trance by Dr. Kinglake, who took the bag from my mouth, indignation and pride were the first feelings produced by the sight of the persons about me. My emotions were enthusiastic and sublime, and for a moment I walked round the room, perfectly regardless of what was said to me. As I recovered my former state of mind, I felt an inclination to communicate the discoveries I had made during the experiment. I endeavoured to recall the ideas; they were feeble and indistinct. One recollection of terms, however, presented itself, and with the most intense belief and prophetic manner I exclaimed to Dr. Kinglake, 'Nothing exists but thoughts; the universe is composed of impressions, ideas, pleasures, and pains!'"

"These remarkable properties induced several persons to repeat the experiment of breathing this exhilarating medicine. Its effects were, as might have been expected, various in different individuals; but its general effect was to produce in the gravest and most phlegmatic, the highest degree of exhilaration and happiness, unaccompanied with languor or depression. In some it created an irresistible disposition to laugh, and in others a propensity to muscular exertion. In some it impaired the intellectual functions, and in several it had no sensible effect, even when it was breathed in the purest state, and in considerable quantities."*

Dr. Reid, in his Elements of Practical Chemistry, gives a very interesting account of the results of the administration of this gas to nearly three hundred of his pupils. Only four disliked it: on a few it produced no effect. The rest were all affected by it in a manner which removed every doubt of its exciting properties. The excitement produced was quite uncontrollable, and generally of the most delightful kind. In a few instances the individual, however, became extremely violent, and required restraint. But in no case was any injurious consequence observed.

I have administered it to many of the Hindu pupils at the Medical College, with precisely similar results, and certainly with the apparent effect of calling into play the peculiar disposition of the person making the experiment. One of our lads, distinguished for his comical propensities, after making a few inspirations burst into a fit of such wild and ludicrous laughter, that over two hundred spectators could not refrain from joining him. Such a laughing chorus I never heard. The boy rolled about the theatre, holding his nose in one hand, and only ceased to utter shouts of laughter when he was quite exhausted by the involuntary exertion.

In general too, I have noticed in Bengal, that during the inhalation of the gas, the pulse becomes slow, the skin damp and rather cold, the face pale, and the lips slightly livid; but I have never known any injury or even discomfort result from the inspiration.

To breathe nitrous oxide, an oiled silk bag, capable of containing several quarts, must be provided, or a bladder, or Nipal paper bag well varnished, may be employed, if nothing else can be conveniently procured. Dr. Reid gives the following excellent practical directions for the experiment: "A tube is fixed to the bag, and a brass connecting tube fitted to the other end of this tube, in order that it may be attached easily

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* See letters on Natural Magic, by Sir D. Brewster to Sir Walter Scott.

to a gasometer, or any other reservoir from which the gas is obtained. The tube may be made either of brass, glass, or hard wood. I generally prefer the latter, as it is not so liable to do any injury when the person breathing the gas has been strongly excited by it, and will not part with it, which is often the case. To prevent also the bad effects that might arise from too frequent an inhalation of the same portion of air, there ought to be an aperture in the side of the tube, which may be kept closed by an assistant placing his thumb upon it when the bag is filling, and during the respiration of the gas; and by removing it when it has been continued sufficiently long, and closing the neck of the bladder with the finger and thumb, no violent measures are required to force the tube from the mouth of the person who has been breathing the gas, as, in this manner, he will respire nothing but atmospheric air through the tube." This form of the tube is represented in *fig.* 12.

During the preparation of this gas, the student may avail himself of the opportunity for performing a beautiful experiment devised by Mr. Emmett, for the preparation of pure nitrogen gas. If a small piece of zinc be introduced into the fused nitrate of ammonia, that salt is immediately decomposed. The zinc takes oxygen from the nitric acid, and an insoluble oxide of zinc is produced; the remaining oxygen of the acid, with the hydrogen of the ammonia, forms water, and the whole of the nitrogen both of the nitric acid and the ammonia is disengaged in the gaseous form. This process affords one of the readiest and most elegant methods of preparing nitrogen gas. The zinc should be attached to a wire sliding through a cork in the tubulure of the retort. The zinc should barely be allowed to touch the surface of the melted salt, as the action is very violent.

BINOXIDE OF NITROGEN, OR NITRIC OXIDE.—(NO_2.)

This is the second in the arithmetical series of compounds which nitrogen and oxygen form. It is best prepared by decomposing nitric acid (NO_5,) by means of copper or mercury. The copper attracts oxygen from the acid in such proportion that one part of the acid is decomposed into nitric oxide (NO_2,) and oxygen. The former escapes in the form of gas, the latter forms with the metal an oxide which unites with the undecomposed portion of the acid, producing a salt termed the nitrate of copper.

The gas may be collected over water in the mode already described. It is colourless, and when quite pure, free from taste, or smell, and does not possess any of the properties of acids.

The most characteristic quality of this remarkable and useful gas is, its great attraction for oxygen, with which it forms an acid vapour, of a rich brown colour, highly irritating and irrespirable, and very soluble in water. This new compound is the *nitrous acid* (NO_4,) mixed with *nitric acid* (NO_5,) regarding both which acids further details will be given in the appropriate place.

The affinity which nitric oxide possesses for oxygen affords us the opportunity of observing clearly the remarkable changes in the secondary properties of matter effected by chemical combination. Oxygen is colourless, tasteless, and inodorous—it excites, but does not irritate our respiratory organs. It does not affect the blue colours of vegetables—it is scarcely soluble in water. The *nitric oxide* itself is so insoluble in water, that it is collected over that fluid: it is, like oxygen, destitute of colour: it does not alter blue vegetable colours—but the instant it meets oxygen in an uncombined state, a rich brown colour pervades the mixture. Thus when we prepare the nitric oxide in open vessels with the materials above mentioned, every bubble of the gas as it comes in contact with the common air deprives it of its oxygen, and the brown coloured vapours of nitrous acid are produced.

To examine the properties of the gas with more precision, we conduct the experiment thus: A bent tube is attached by a stout cork well waxed to a small bottle one-third full of dilute nitric acid—some pieces of copper are dropped in,* the cork and tube introduced, and the extremity of the tube dipped beneath the surface of the water in the pneumatic apparatus already described. The first few bubbles of nitric oxide, with the oxygen of the air in the phial, form the brown vapour of nitrous acid, which is soon absorbed by the water, and a copious stream of transparent, colourless gas, the nitric oxide, ascends through the water, and is collected in jars or phials in the usual manner.

If 100 measures (say cubic inches) of this gas be mixed over water, with an equal volume of common air in *a very wide* tube or jar, red vapours are forthwith formed, and the water rises in the jar until the red colour entirely vanishes. On measuring the remaining gas, it is found to amount to 116 volumes or cubic inches; 84 have disappeared, or been dissolved by the water. Of these 84 volumes one-fourth is oxygen gas. When we come to treat of the nature of the atmosphere in detail, I will notice again the changes which occur in this experiment. Very few inflammable bodies will burn in an atmosphere of this gas. A taper or even burning sulphur immersed in it, is at once extinguished. But a piece of charcoal or phosphorus if well inflamed, and then introduced, will continue to burn. With an equal volume of hydrogen, the mixture will inflame by contact with a lighted match, and burn quickly with a rich white flame. The results of this combustion are water and pure nitrogen gas, which is readily explained—thus, 100 cubic inches of nitric oxide contain 50 nitrogen, 50 oxygen—and 50 oxygen or one

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* Mercury or sugar may be used instead. If the latter, oxalic acid is formed, and remains in the retort.

volume, with 100 hydrogen or 2 volumes, form water—setting 50 of nitrogen free.

The nitric oxide is quite irrespirable; for the moment it enters the mouth, it combines with the oxygen of the air and becomes nitrous acid,—a vapour so irritating and corrosive, that a single inspiration of it into the lungs would lead to the destruction of life.

There are various modes in which the composition of this gas may be demonstrated. The most conclusive is that invented by a distinguished French chemist, Gay Lussac. There is a metal called Potassium, which has so eager an attraction for oxygen, with which it forms the alkali called potash, that it decomposes every substance containing that element. Gay Lussac heated this metal in contact with 100 cubic inches of nitric oxide; 50 cubic inches of pure nitrogen were left, and the potassium was changed into potash, and increased 17½ grains in weight. Hence, as

50 cubic inches of oxygen weigh,............... 17,054 grs.
50 ditto ditto nitrogen ditto,........................15,083 grs.

100 cubic inches of nitric oxide should weigh 32,137 grs. which result was directly obtained by experiments performed by other eminent chemists. Sp. gr. 1030—Symbol NO_2.

When a current of this gas is passed through a solution of the proto-sulphate of iron* in water, the gas is dissolved, and the solution becomes black. If this solution be heated it gives out the gas again. It was formerly much used for analysing atmospheric air, the oxygen of which this solution withdraws, but the results of the experiments are so inaccurate, from many interfering circumstances, that this method is now abandoned altogether. I have, however, given a figure of the apparatus for directing a current of the gas through the solution, (see *fig.* 13), because the student will find it extremely useful in various experiments with a great number of other gaseous bodies.

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* A green salt, commonly sold in the bazars by the name of *heera-kasis.*

I have described the nitric oxide as a "useful" gas, and it well deserves the epithet, being consumed in immense quantities in the manufacture of sulphuric acid, the most universally valuable of all the compounds used in the chemical arts. The next compound of nitrogen and oxygen is also interesting for a similar reason, for on our knowledge of its composition, the theory of the manufacture of sulphuric acid is chiefly dependent.

THE HYPO-NITROUS ACID.—(NO_3.)

This is a compound of 150 volumes of oxygen and 100 nitrogen, and is prepared by mixing 400 measures of nitric oxide with 100 of oxygen over mercury in a tube containing potash, and cooled to 40° below the freezing point of water.

At ordinary temperatures this acid is an orange-coloured vapour, which by intense cold may be condensed into a green liquid. When mixed with water it is resolved into nitric oxide, which escapes with effervescence, and nitric acid which remains dissolved in the water.*

But the most remarkable property of the hypo-nitrous acid is, that with sulphurous acid gas, (sulphur 1 eq. oxygen 1 eq. —see "Sulphur")—and watery vapour it forms a white crystalline substance, composed of the hypo-nitrous and sulphuric acids. When this compound is mixed with water, the sulphuric acid is dissolved, and the hypo-nitrous acid decomposed into *nitric oxide* and nitrous acid. Under the head of "Sulphuric Acid" this subject will be again referred to.

NITROUS ACID.—(NO_4.)

By mixing 200 measures of nitric oxide (nitrogen 100, oxygen 100) with 100 of oxygen in a perfectly dry glass vessel, exhausted of air, Sir Humphrey Davy formed nitrous acid

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* Nitrate of potash heated till part of its oxygen is evolved is changed into the Hypo-nitrate, which is known by its giving brown fumes with acetic acid.

vapour, a compound of nitrogen 100, oxygen 200 measures. When the union is complete, the elements contract to one-third of their original volume, or as Dr. Turner expresses it, 100 measures of nitrous acid vapour consist of 100 of nitrogen and 200 of oxygen. The vapour is orange-red colour, is strongly acid, changing vegetable blue colours to red. It is absorbed by water, and thereby decomposed into nitric oxide and nitric acid. It supports the combustion of phosphorus and carbon, and is quite incombustible itself.

This acid may also be prepared in the liquid state from a compound termed the nitrate of lead. As the properties of the liquid acid are of considerable interest, I shall describe the steps of the process at some length.

To prepare the nitrate of lead, small pieces of sheet lead are to be boiled in dilute nitric acid. (1 ounce of lead to 3 of acid will give enough for the experiment.) The lead takes oxygen from the acid, nitric oxide is evolved, and the oxide with undecomposed acid forms the salt called nitrate of lead, which is obtained in a white crystalline mass on evaporating the mixture to dryness. The preparation may be made in a tea cup imbedded in sand, placed in a little earthen pot, and the whole gradually heated over a brisk charcoal fire. The operator must take care to avoid the fumes and drops of acid, which are apt to be ejected during the process.

To prepare liquid nitrous acid from this nitrate of lead, introduce about half an ounce into a glass tube sealed at one end: and following the easy directions given in the Appendix, draw out at the blow-pipe the neck of the tube into the form represented in *fig.* 14; next introduce, the narrow end through a waxed cork into a small phial, surround the phial with a mixture of ice and common salt, and heat the part of the tube containing the nitrate of lead with a large spirit lamp flame, till ruddy vapours cease to be disengaged.* These vapours are nitrous acid, which is condensed to the liquid state by the cooling mixture. A small quantity of pure liquid nitrous acid

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* The residue is a mixture of protoxide and peroxide of lead.

may thus be easily prepared, and on experimental examination it exhibits some very curious properties.

It boils at the temperature of 82°, far below that of the atmosphere in the hot season; and hence when we attempt to let a few drops fall from the phial to the ground, before these can reach it, they disappear in copious clouds of red and acid vapour.

If a little strong sulphuric acid be cooled by the mixture of ice and salt, and then poured into the liquid nitrous acid, a white crystalline solid will be formed; that previously described as a compound of sulphuric and hypo-nitrous acid.

If mixed with water it is immediately changed into nitric acid and nitric oxide; the latter escaping with effervescence.

The student should recollect that the liquid acid thus prepared is termed the *anhydrous*, (meaning free from water,) to distinguish it from another acid *commonly called* the nitrous acid, which is a mixture of water, nitric and nitrous acids, to which I shall advert under the next head, when he will find that the knowledge of the leading properties of the *tru*e nitrous acid, is not destitute of practical utility.

NITRIC ACID—(NO_5.)

Nitric acid gas or vapour has not hitherto been obtained in a separate state. In the purest form in which we know this acid, it is united with a definite proportion of water, or is, in chemical language, a *hydrate* composed of two acid and three water.

In this state, nitric acid (the aquafortis of the older writers) is a pale yellowish liquid once and a half as heavy as water; that is to say, that were we to compare the weight of equal bulks of water and nitric acid, if the measure of water weighed 1000 grs. the same measure of acid, by which number accordingly its specific gravity is expressed, would weigh 1,500.

The nitric acid is one of the most powerful of acid bodies. It reddens the vegetable blue colours. With alkalies, such as potash, soda, and ammonia; with lime and the other earths; and with the oxides of the common metals, it forms neutral salts, termed nitrates. It is necessary to remind the reader here, that these salts are called *neutral*, because the peculiar properties of the acid and the base are totally altered by their union; and this term is used moreover, in every instance in which an acid and these bodies unite in such proportions that neither the properties of the acid nor of the base predominate.

Nitric acid boils at 248° F. If the acid contain more water than in the proportion necessary to give it a specific gravity of 1420, i tbecomes stronger by being heated; but if the acid contain less water, or, in other words, have a greater specific gravity, it is weakened by being brought to the boiling point.

Nitric acid, exclusive of the water which renders it a hydrate, is found on analysis to consist of 1 eq. of nitrogen and 5 eq. of oxygen by weight, or 100 nitrogen, 250 oxygen by volume. It is easily resolved into these gases by bringing its vapour into contact with red hot fragments of porcelain, heated to redness in a tube of the same kind. The fragments of porcelain are used merely for the purpose of increasing the heated surface with which the acid vapour is brought into contact ,while they are not acted on chemically by it. The experiment, however, is one which the student in this country would find very difficult to perform.

From the great quantity of oxygen which nitric acid contains in the condensed state, its range of chemical attraction is very wide, and it communicates its oxygen very readily to a great number of substances having an attraction for that element. Thus many of the simple metals, such as iron, copper, lead, silver, mercury, &c. are changed into oxides by contact with this acid: and if there be a sufficient proportion of the acid present, the oxide and the acid form a salt termed a *nitrate*. Besides its action on metals, it also oxygenizes various non-metallic bodies. Iodine is converted into iodic acid when boiled with it; phosphorus is oxidized to its maximum and becomes phosphoric acid. There are, again, numerous compounds of carbon, and hydrogen, and oxygen, which when mixed with this acid, attract its oxygen so powerfully that heat and light are evolved. Thus, when nitric acid is poured on warm oil of turpentine, the mixture bursts into a flame.* It decomposes anima lmatter, to which it gives a bright yellow stain; and thus, if applied to the skin, it destroys its texture and organization, leaving a characteristic yellow mark wherever it has touched.

The nitric acid is manufactured in very large quantities† for use in the arts and in medicine, as a chemical re-agent, and as an ingredient in the preparation of many medicinal articles. Examples of its utility will, in fact, occur in almost every succeeding section of this volume.

For the preparation of this acid several processes have been adopted, all founded on the decomposition of the salts called *nitrates* by an acid named the sulphuric, which separates the base of the salt and sets the nitric acid free.

The method directed in the London Pharmacopœia is the best yet devised. Equal weights, say 100 parts, of nitrate of potash (saltpetre) and strong sulphuric acid are employed. The salt, previously well dried, is placed in a glass retort (see *fig.* 15.) The sulphuric acid is then poured over it, and heat applied, on the large scale, by a suitable furnace;—where small quantities of the materials are used, by a spirit or oil lamp, as represented in the drawing. The vapours of nitric acid are condensed in a receiver kept cold by a wet towel. This proceeding is termed "distillation," and is one of universal application in experimental chemistry.

Of the materials employed, one equivalent of nitrate of potash contains 54 or 1 eq. of acid, and 47,3 or 1 eq. of po-

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* We have witnessed this also on pouring strong nitric acid on powdered morphia.

† The natural origin of nitric acid is fully discussed under the article Nitrate of Potash in a subsequent chapter.

tash; total 101.3. 98.20 parts sulphuric acid contain 2 eq. of sulphuric acid in the dry state, (40.1×2=80.2) and 2 eq. of water (9×2=18.) When decomposition ensues, the 2 eq. of dry sulphuric acid unite with the 1 eq. of potash and ½ an eq. of water, forming a salt called the bi-sulphate of potash. The nitric acid of the saltpetre is consequently liberated in combination with 1½ equivalents of water, which I have already stated to be essential to its formation.

Thus the water necessary for the existence of the nitric acid is derived exclusively from the sulphuric acid; and as 2 equivalents of sulphuric acid only contain exactly the proportion of water that is required for the nitric acid and the resulting salt, it must be obvious, that were we to employ less sulphuric acid, the process would not succeed. Hence, where from economical motives the manufacturer employs a smaller quantity of the sulphuric acid, a great proportion of the nitric acid is lost, being decomposed and changed into nitric oxide and nitrous acid, the moment it is disengaged from the saltpetre. If the process above described be carried on with one-half the quantity of sulphuric acid, the product in the receiver will be a mixture of nitric and nitrous acid, impregnated with nitric oxide. It will be of a deep brown colour, evolve ruddy suffocating fumes when exposed to the air, and constitute in this state the fuming nitrous acid of pharmaceutical writers.

There is another disadvantage in using the smaller proportion of the sulphuric acid, the salt formed is a neutral sulphate which is sparingly soluble in water, and removed from the retort with much difficulty.*

Of the other processes for preparing nitric acid, the best is by heating together a mixture of saltpetre and sulphate of iron. This sulphate of iron when heated to redness gives

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* Since the publication of the first Edition of this Manual, *nitrate of soda* has nearly superseded saltpetre in this process in Europe. Its first cost is cheaper, it yields more acid, with less expenditure of sulphuric acid and fuel; 85.3 parts of nitrate of soda yield 54.0 of nitric acid.

out its acid, which then decomposes the nitre, and sets the nitric acid free. This is the process followed in the Honorable Company's Dispensary in Calcutta. The materials are heated in an iron retort, and the acid condensed in a series of stoneware jars.

The Hindus prepare an acid which they call *shora ke tezáb*, by heating together the salt called alum and saltpetre. Alum is a compound of sulphuric acid, oxide of aluminium and potash. When heated to redness with nitre, the sulphuric acid takes part of its potash, and the oxide of aluminium unites with more, the nitric acid being disengaged. The operation is conducted in common earthen vessels; the product is a mixture of nitrous and nitric acids.

As we find nitric acid in commerce, it is generally mixed with small portions of sulphuric and muriatic acids; the first proceeding from accidental admixture in the course of manufacture; the second from common salt (muriate of soda) existing as an impurity in the nitre used in the preparation. For the exact detection of these acids, directions will be found under their respective heads.*

If a current of the nitric oxide gas be directed through strong nitric acid, the former gains, the latter loses oxygen, and both become the nitrous acid. It is singular, too, that the colour of the resulting acid varies according to the strength of the nitric acid employed. On performing the experiment for instance, with acid of the specific gravities 1.15, 1.35, 1.40, and 1.50, the colour will be *blue* in the first, *green* in the second, *yellow* in the third, and *brownish red* in the fourth. The strongest acid which can be made is of the sp. gr. 1,521.

In the section devoted to the subject of the chemical inquiries necessary in the discovery of poisons, in cases of medico-

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* The sulphuric acid is detected by the nitrate of baryta, white sulphate of baryta being precipitated: *see sulphuric acid*;—the muriatic acid by the nitrate of silver, which precipitates chloride of silver: *see muriatic acid.*

legal investigation, minute directions are given regarding the detection of the nitric acid. The principal tests for the pure acid are—*first*, copper or mercury, which when heated with it in a tube, evolve ruddy fumes of nitrous acid; *secondly*, morphia, a particle of which by the minutest drop of nitric acid, even if diluted with five times its volume of water, produces a blood-red colour. The experiment should be performed on a white porcelain surface.

Before I proceed to the subject of atmospheric air, the remaining compound of nitrogen and oxygen, it is desirable to notice carbon and its oxides, one of which occurs in the air itself, and is closely connected with the respiration of animals, and the functions of the vegetable kingdom.

SECTION V.

CARBON AND ITS OXIDES.

Carbon is the generic name of a simple substance with which, in various forms, every one is familiar. It is the basis of vegetable matter,—it exists extensively in the mineral form—it is an ingredient to a large amount in the structure of all organized beings; and in combination with oxygen, hydrogen, or nitrogen gases, it is met with abundantly in many natural productions.

In these various sources its physical and secondary properties are materially different, according to the element with which it is combined, or from which it is obtained. Thus vegetable carbon, or *charcoal* as it is commonly termed, is black, fibrous, porous, readily inflammable in air, easily divided by cutting instruments, and possessed of many other equally well known properties. *Pure mineral carbon*, or the *diamond*, as it is popularly termed, is brilliant and translucent to an unrivalled degree of splendour, requires all the art of the lapidary to effect its division, and though perfectly inflammable, yet needs the skill of the chemist to accomplish its combustion. Striking as these differences doubtless are, nevertheless the chemical identity of the two substances is as conclusively established, as any other fact in science at all apart from ordinary trains of observation.

It is perhaps expedient to remind the student that the mechanical differences I have described, are not more startling than some which are occasionally presented by other elementary or compound bodies. Water, for instance, may exist as *steam*, an invisible, impalpable, *dry* aëriform vapour. It may occur in the intermediate state in which we daily behold it, or it may be solidified in the form of ice to such a degree of cohesion, as to afford materials for the construction of dwelling places, or on a still grander scale when it constitutes the icebergs of the arctic oceans, or the glaciers of the Alps and Himalayas. If then water can present such totally opposite mechanical forms under the mere influence of heat or cold, it cannot seem entirely inexplicable that *carbon* also, may be modified in its mechanical properties by the operation of causes still unrevealed to the modes of investigation we yet have at our command.

Let us now see the proofs of the identity of carbon in its several states. These proofs are derived from the most conclusive of all evidence,—the consideration of the numerous compounds carbon is capable of forming with other simple substances, such as oxygen and hydrogen gas.

The force of the attraction existing between oxygen gas and the other simple substances or elements, has been already shewn in a very striking point of view, in the account given of the constitution of water, and of some of the combinations of nitrogen. Now we find that if we take a particle of vegetable carbon (charcoal), mix it with nitre, and heat it in a tube, a gas is evolved, having very remarkable properties. The gas is soluble in water, it turns the vegetable blues red; it is sour to the taste; it is much heavier than oxygen gas or atmospheric air; it extinguishes flame; it destroys life, and that with such positive energy, that a mixture of one part of it with four of common air is still a deadly poison. Submitting this gas to further examination, its nature can be readily proved. Potassium, as I before stated, is a metal which has a most energetic attraction for oxygen, with which it forms a compound called potash. If the gas obtained by heating nitre and charcoal be exposed to heated potassium for some time, potash is gradually produced; the gas, therefore contains oxygen. A black powder is also deposited, and this on examination is found to be *carbon* or *charcoal.* The weight of the *oxygen* and *carbon,* thus separated from the gas, is further found to be equal to that of the whole of the gas operated on; therefore, the gas is solely composed of carbon and oxygen, and from its acid properties, and according to the principles of nomenclature I have already explained, it is called *carbonic acid* gas. Its nature being thus already established, we find that this carbonic acid may be obtained from many sources. The simplest and most intelligible is by exposing charcoal to heat in a vessel of oxygen gas.

On subjecting the *diamond* to the same processes, on heating it with nitre or in a vessel of oxygen gas, every particle of the diamond is consumed, and the same gas, carbonic acid, is produced,—possessed of exactly the same properties, all of which we shall presently study in detail. If further proof were required, we can have recourse to hydrogen, which forms also some remarkable compounds with carbon, and we find that whether pure wood charcoal or the diamond be used, the products are precisely alike. The conclusion is hence irresistible, that *vegetable* carbon and diamond are identical in their ultimate constitution, and that the points of dissimilarity are solely dependent on a difference in mechanical texture.

Some curious experiments have, we are informed on very high authority, been recently made in Edinburgh, which shew that *silicon* is another form of carbon, and *flint* of carbonic acid.

I have been induced to dwell on this point at some length, because it has often proved a serious obstacle to many on the very threshold of the science.

The production of carbonic acid being, therefore, the certain test of the presence of carbon in any substance, and as the quantity of the carbon may also be estimated by the same means, the study of this gas consequently becomes a matter of great importance. We shall, however, in the first place, now that we know how the general identity of the various kinds of carbon is proved, cursorily examine the leading varieties themselves.

The first is the *diamond*, which is the purest of all, containing nothing but the element *carbon*. It is the hardest substance in nature, occurring in its most perfect state in the form of an octohedron, or a crystal with eight sides. Heated to redness in the open air it is entirely consumed, producing solely carbonic acid.

Vegetable charcoal is the next variety. It is obtained by heating wood to redness in close vessels, such as iron cylinders, so that the air cannot have access to it. Acetic acid, tar, water, and other proximate principles are distilled over during this process. A very pure charcoal is made by heating starch, or sugar, or resin, in this way.

Animal charcoal, or ivory black, is made by the burning of bones, or other animal matters in close vessels. It is very impure, being mixed with several kinds of earthy matter, which may be removed by washing with muriatic acid.

Mineral carbon embraces several varieties of coal, of which the *glance* coal, or *anthracite*, is the purest, the others being all more or less associated with resinous, sulphurous, or earthy matters. For the present we shall pass over the points of difference in these varieties of carbon, and restrict ourselves to the consideration of the vegetable kind.

Good vegetable carbon is hard, brittle, black, quite insoluble in water, and very little affected by acids or alkalies. It does not rot nor undergo decomposition when exposed to air and moisture; and, heated in close vessels, it bears the most intense heat without a change. One of its most interesting properties is the absorption of gases which it effects. When heated to redness, plunged under mercury, and then introduced into the gas to be examined, it is found in the course of 24 hours to absorb of—

Ammoniacal gas,...	90	times its volume.
Muriatic acid,...	85	
Sulphurous acid,...	65	
Sulphuretted hydrogen, ...	55	
Nitrous oxide,...	40	
Carbonic acid, ...	35	
Oxygen,...	9	
Nitrogen, ...	7	
Hydrogen, ...	1	

This property is solely owing to its porous or spongy texture. It is not so readily understood why it absorbs more of one gas than another, an effect which the best chemists attribute not to differences in degree of affinity, but in amount of the elasticity of the gas. Thus hydrogen, which is the *most* elastic, is that absorbed in the least proportion. By careful management carbon also absorbs most of the odoriferous and colouring principles of animal and vegetable substances. Mixed in powder with putrid animal or vegetable matter it gradually deprives it of its offensive smell; and when various colouring substances of vegetable or animal origin are similarly treated the colour fades and disappears. Numerous instances of practical and useful applications of this fact will occur in the sequel of this volume.

But its most important property is its combustibility in oxygen, and total conversion thereby into carbonic acid gas. I have already mentioned some of the leading properties of this gas,—another, one of much importance, depends on the compounds this carbonic acid forms with lime and baryta. Lime is an acrid substance, soluble in water to a considerable extent, and prepared by heating chalk or shells to redness.

When a solution of lime is exposed to any source of carbonic acid, an insoluble white compound, the carbonate of lime, is formed. This compound is commonly called chalk, and from it again we can obtain the carbonic acid, either by heating it to redness, or by adding any other acid, for nearly all have a stronger affinity for lime than the carbonic. Thus adding a little muriatic, or sulphuric, or nitric acid to chalk—a sulphate, muriate, or nitrate of lime is formed, and the carbonic acid set free. We can again reproduce the chalk by passing the gas through lime water. The chief sources of carbonic acid are the combustion of carbonaceous matters; the respiration of animals and plants; the rotting or decomposition of vegetable and animal matter; fermentation, &c.

Hence if we breathe through a tube or quill into a vessel of lime water the liquid soon becomes turbid, a carbonate of lime being formed by the carbonic acid evolved from our lungs.

Now, reserving the explanation of the production of carbonic acid in respiration, we may anticipate that, as all animals evolve the gas in considerable quantities—as all decomposing plants,—as every fire that is lit, furnish it in perpetual abundance,—the atmosphere should contain it in a notable proportion. That such is the case is readily proved by simply exposing a vessel of lime water to the air, when its surface soon becomes covered with carbonate of lime. The proportion present however, is happily minute, 10,000 grains of air containing but $4\frac{1}{10}$ grains as the average quantity. How fortunate this is may be judged by the fact, that air containing but one-fourth of its volume of this acid destroys combustion and is fatal to life. The pure carbonic acid causes immediate insensibility. Diluted with air it acts as a narcotic poison, and it has proved fatal in either of these modes to thousands of individuals. The former generally occurs to persons descending incautiously into the vats of brewing houses, into old wells, and pits where vegetable or animal decomposition is going on. Of the second mode of poisoning there are multitudes of examples, one of the most remarkable of which occurred in the instance of the murder of the English prisoners in the "Black Hole" of Calcutta, when of 146 individuals only twenty-three survived the incarceration of a single night.

Carbonic acid is composed of 1 eq. carbon, 2 eq. oxygen. It is found, moreover, that carbonic acid gas contains its own volume of oxygen, that is, that 100 cubic inches of carbonic acid gas contain 100 cubic inches of oxygen. Hence the difference of the weights of equal volumes of these gases shews the exact quantity of carbon combined with the oxygen. If we consider the carbon in carbonic acid as a vapour, 100 cubic inches weigh rather more than 13 grains. The proportion in which carbon enters into the composition is found to be 6.12, the oxides of carbon being respectively thus constituted—

Carbonic oxide, carbon 1 eq. 6.12. Oxygen 1 eq. 8=14-12
———— acid, carbon 1 eq. 6.12. Oxygen 2 eq. 16=22-12

For experimental purposes the carbonic acid is very readily prepared from chalk and carbonate of lime, by mixing it with any stronger acid. It is a curious and instructive lesson in the manipulation of gases, to remark the phenomena of its collection. Being much heavier than atmospheric air (100 cubic inches weighing 47¼ grains) it is easily procured for experiment. By using the bottle and bent tube previously described, and introducing the bent tube to the bottom of a flask or jar containing common air, the carbonic acid will remain like water below, and collecting as it is evolved will expel the common air from the receiving vessel. By introducing a lighted match from time to time, we can find the level to which the acid gas has reached; for the moment the light touches it, it is extinguished as if dipped in water. Even burning sulphur and phosphorus plunged into this gas shew the same result. When we have filled a vessel with the gas we may pour it out like a liquid into another. An amusing experiment may be made by pouring the gas over a small taper in a common table shade, the taper will forthwith be completely extinguished. The carbonic acid may be pumped over from vessel to vessel, in short it may be managed as easily as water, or any other liquid.

Natural accumulations of carbonic acid sometimes take place to a considerable extent. In the Grotto del Cani, in Italy, there is a perpetual extrication of the gas to such an extent above the floor that small animals immediately perish when they enter. In the springs of Saratoga, in America, a similar evolution takes place. In the holds of ships, in deep cellars and ice pits, in wells containing decaying vegetable matter, indeed in countless similar localities, the like effects are commonly witnessed. Innumerable expedients have been attempted with a view to ventilate these dangerous reservoirs. Where an opening can be practised below the level of the collection of gas it will run out like water, and pure air supply its place. From the holds of ships or cellars it can be pumped out easily by adjusting a leathern hose or pipe to a portable pump, or any similar contrivance.

When a person has fallen into such a collection of gas, the attempt to extricate him is extremely dangerous. The diver who descends beneath water, can, it is true, suspend his respiration safely for a considerable time, but he is in a liquid not deleterious in itself, and the presence of which reminds him constantly that he must not attempt to breathe. But in an atmosphere of carbonic acid, if for a moment we forget its nature, and yield to the desire of respiration, instantaneous insensibility is produced. With one end of a húkah snake, or similar flexible tube in the mouth, and the other end held by an assistant in the pure air, the adventurer may descend and explore the reservoir of "choke damp" with perfect safety.

Though insensibility is thus quickly caused, life is not so soon destroyed. Very many individuals have been rescued from apparent death under these circumstances. The most successful treatment is by dashing the body with cold water, holding ammonia to the nostrils, and, where it can be procured, by pressing oxygen gas through the mouth and air passages into the lungs.

Carbonic acid abounds in many mineral springs, to the waters of which it imparts a highly agreeable, and rather pungent flavour. It is easy to impregnate common water or other fluids with this gas by means of the apparatus termed Nooth's (*fig.* 16), or Woolfe's (*fig.* 17). Chalk being introduced into the bottles, *a*, and a dilute acid, sulphuric or muriatic, added, carbonic acid is quickly disengaged. In Nooth's apparatus the gas lifts a valve opening upwards into the second bottle, and gradually ceasing to be absorbed, it forces the fluid into the uppermost bottle, by which means the gas is subjected to considerable pressure. In Woolfe's bottles the bent tubes successively lead the gas through the fluid into *b*, *c*, &c. A tube of safety, (*d*) as it is termed, is employed in each, in order that common air might enter should any irregular absorption of the gas take place in one of the bottles.

There is a natural process termed fermentation, which readily takes place in all vegetable matter containing sugar, and also in many kinds of animal matter, as will be subsequently explained. During this process carbonic acid is copiously generated. This fermentation is one step in the manufacture of beer, ale, champagne, and similar beverages, and the gas being forcibly retained in the liquid, escapes with effervescence on the pressure being removed by uncorking the bottle.

CARBONIC OXIDE.—($CO1.$)

The protoxide of carbon, or the carbonic oxide, is the result of the deoxidation of carbonic acid. If we pass a current of this acid over red hot iron, the iron attracts half its oxygen, and carbonic oxide is formed. Or it may be prepared by heating a mixture of carbonate of lime and iron filings to redness, or by directing a current of carbonic acid gas repeatedly over charcoal heated to redness, in a porcelain or iron tube.

This gas differs very widely from carbonic acid. It is combustible, insoluble in water, has no acid properties, and does not precipitate lime water.

The carbonic oxide extinguishes flame, and is deleterious to life, and when burned by itself affords nothing but carbonic acid. Its composition is easily ascertained by inflaming it with oxygen gas by the electric spark. 100 measures require 50 oxygen, and 100 measures carbonic acid are produced. Hence carbonic oxide and carbonic acid both contain the same quantity of carbon, but the acid has twice as much oxygen as the oxide, and 100 cubic inches weigh but 30 grs. and a fraction.

The carbonic oxide and acid may be obtained at once from a compound named *oxalic* acid, under which head the reader will find detailed instructions for conducting this very beautiful experiment.

A familiar instance of the production of carbonic oxide occurs constantly in the lighting of charcoal fires. The lower layer of charcoal is oxidized by the atmospheric air, and carbonic acid is formed. This acid ascending through the glowing charcoal above is again deoxidized and carbonic oxide formed, which burns at the surface, occasioning the pretty blue lambent flame with which we are so well acquainted.

SECTION VI.

ATMOSPHERIC AIR,—ITS NATURE AND ANALYSIS,—ITS INFLUENCE ON THE RESPIRATION OF ANIMALS, AND VEGETATION OF PLANTS.

As we have now studied in detail the properties of oxygen, hydrogen, nitrogen, and carbon, the four elementary substances which enter into the composition of atmospheric air, and of the organized beings which depend on that atmosphere for their existence, we are prepared to examine the properties of that fluid with due accuracy, and to investigate also some of the phenomena over which it presides.

In this section I propose to give a brief account of the progress of discovery regarding the nature of the air, of the several processes by which its constitution is now ascertained and demonstrated, and of the controversies at present pending relative to the mode in which its elements are combined.

The early chemists, from the mysterious days of Tubalcain, the son of Lamech, till the middle of the 17th century, contented themselves with regarding the atmosphere as an *element* or simple body, and this opinion is still current among the uneducated of all nations. The first fact which seems to have directed the attention of philosophers towards the right path, was an experiment performed in 1629 by Le Brun, a French Apothecary, who found that when a pound of lead was heated in the open air, it increased considerably in weight, from which he inferred that it had separated something from the air,—but what that something was, he wanted the sagacity to discover. An English natural philosopher Hooke, made the next step towards the discovery by proving, that the air is necessary to support combustion in all its ordinary forms; and, to use his own words, "that the solution or combustion of these bodies is made by a substance inherent in air, *and like, if not "the very same with that which is fixed in saltpetre."* But Hooke went no further. He knew not what it was the nitre or saltpetre contained; it was reserved for another to add this final link to the chain.

Some years after Hooke's essays appeared, another English chemist, Mayow, turned his mind to the same subject; and though he failed in the actual identification of the various ingredients of the atmosphere, nevertheless the facts which he accumulated, and the theoretical views he derived from these, left but few difficulties to be obviated by his successors. He proved that there existed in the air a substance necessary to life and flame—*that it was identical with that "pent up"* as he expresses it, *in saltpetre*—that when metals are burned they absorb it, and therefore increase in weight,—that a similar change may be effected by nitric acid; and that the same principle is equally essential to the respiration of animals and the vegetation of plants. It is impossible not to admire the deep sagacity of this great man, who thus may be said to have predicted or anticipated the discoveries, which one hundred years later perfectly explained and confirmed all his conjectures.

The first of the substances present in the atmosphere which was completely and satisfactorily identified was the *carbonic acid*. This was detected in 1750 by Dr. Black, of Edinburgh, who found that chalk when heated expels this gas and becomes caustic—and that it again absorbs the gas it evolved if exposed to it when cold. Dr. Rutherford applied this fact successfully to the study of the air. He found that when animals were confined in a portion of air, they produced the same gas as that evolved by the combustion of chalk; that on exposing the air thus deteriorated to lime the carbonic acid was absorbed, but that *another gas remained* equally incapable of supporting respiration or flame, but not absorbed by lime or other alkalies. *Nitrogen* gas was thus added to the recognized ingredients of the air.

It is a curious subject for reflection, that *oxygen* gas, the most important and striking of the whole, should have been the last which the analyst of the atmosphere discovered. In 1774, Priestley first procured *oxygen* in the separate state from the red precipitate of mercury and from red lead. He shewed the power this gas possesses over combustion, and the production of carbonic acid when vegetable fibre is burned in it. He also proved, what Mayow had before suspected, that carbonic acid is decomposed by growing vegetables, and replaced by pure oxygen; and thus, that the air we breathe, though contaminated by our respiration and our fires, has in the vegetable world a source of restoration to its original salubrity. The experiment by which he proved this fact was remarkable for its simplicity and conclusiveness. He rendered air incapable of supporting combustion by keeping a taper in it until it was extinguished, and then introduced some sprigs of healthy, growing herbs. In a few days it was invariably found that the air had recovered its former power of supporting flame and life.

The several ingredients of atmospheric air having thus been discovered, one important step still remained; namely, to ascertain whether these are present in a fixed proportion, and what that proportion is. This was accomplished by Lavoisier in 1775, a year after Priestley's discovery of oxygen.

From the time of Lavoisier to the present day, the only addition to our knowledge regarding the constitution of the air relates to substances accidentally, but not invariably present, such as traces of carburetted hydrogen, discovered recently by Bousingault, muriatic acid in the neighbourhood of the sea, and watery vapour in variable proportions. The air may thus be stated in a tabular form, to consist of

Invariable Ingredients.

Oxygen, ...	21
Nitrogen, ...	79

Carbonic acid, *a trace*, 4 in 10,000.

Variable.

Watery vapour.
Carburetted hydrogen.
Muriatic acid, and various exhalations.

The art of analysing air with the view to demonstrating its composition is termed *Eudiometry*, a word of Greek origin, meaning the correct measurement of air. The instruments employed are still called Eudiometers, some of which I shall now proceed to describe. They are all founded on the laws of chemical attraction or affinity, by means of which the carbonic acid, the oxygen and watery vapour, may be separated from the nitrogen, leaving this in the uncombined state.

The presence and quantity of watery vapour are estimated by Daniell's Hygrometer, of which an account is given in the Appendix.

The proportion of carbonic acid is ascertained by agitating a certain volume (at least 500 inches) of air with a solution of caustic baryta in a large and accurately stoppered glass bottle. Carbonate of baryta is formed, may be collected on a filter, dried and weighed; 98 grains correspond to 22 grains or 46 cubic inches of carbonic acid.

To dry air for analysis, it should be enclosed in a large glass jar inverted over mercury, and in contact with some pieces of broken chloride of calcium (fused muriate of lime).

The air being thus dried and freed of carbonic acid, may be deprived of its oxygen by various Eudiometrical processes. Of these I shall only particularise those by nitric oxide—hydrogen, phosphorus, and lead.

1.—Mix in a wide graduated jar over water 100 measures of air and 100 measures nitric oxide. Red vapours form and quickly disappear. The diminution amounts to 84 measures, of which one-fourth is oxygen.

Two equivalents of oxygen here combine with one of nitric oxide to constitute nitrous acid—and two more eq. of oxygen combine each with one eq. of nitric oxide to form hypo-nitrous acid. Thus the oxygen re-acts on thrice its volume of nitric oxide, so that when we divide the amount of the condensation by four, the quantity of oxygen consumed is ascertained.*

2.—By mixing 40 measures of hydrogen with 100 measures of air in a tube over mercury, and passing the electric spark, or introducing a small piece of platinum sponge, or igniting a platinum wire by the voltaic battery explosion takes place; the 40 volumes hydrogen unite with 20 oxygen to form water, leaving 80 of nitrogen in the tube. In this experiment it is necessary to operate with very small quantities of the gases to prevent a dangerous explosion.

3.—If a small piece of phosphorus (see that head) be introduced into 100 measures of air confined over mercury, and if the phosphorus be gently heated by bringing a hot iron near the tube, the phosphorus will remove all the oxygen and form phosphoric acid. The rising of the mercury on cooling will shew the absorption to have amounted to 20 volumes.

4.—A very beautiful and extremely simple mode of Eudiometry has been recently invented by the celebrated Saussure, (*Journal de Pharmacie*, September 1836.) He finds that lead in fine grains, if moistened with water, absorbs oxygen rapidly at natural temperatures. On this fact he founds his ingenious process. Weigh a stoppered bottle accurately; introduce an ounce of granulated lead moistened with water: stop the bottle and let it stand for a few hours, then invert the bottle in the water bath; remove the stopper and the water will ascend in the bottle, until it shews that one-fifth of the original gaseous contents has disappeared. Now stopper the bottle, remove it, and having dried it externally, weigh it again. As 252½ grs. of water represent 1 cubic inch, the increase of weight by the absorption of water will shew precisely how much oxygen has been absorbed.

These Eudiometrical experiments have been practised by the most skilful chemists in all quarters of the globe, in

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* This method is difficult and uncertain, and now never had recourse to.

every variety of locality—at the level of the sea—on the summits of lofty mountains—on the pestilential coasts of Africa and South America—in populous cities, some, too, infected with epidemic diseases—in the wards of hospitals and in crowded assemblies; and every where with the same result. The proportion of oxygen and nitrogen is universally the same; the amount of carbonic acid fluctuates to a trivial extent.

Having thus shewn the proportions in which the gases unite, we may next inquire how or in what manner they are combined with each other. On this point much diversity of opinion has existed, some maintaining it to be a chemical, others a mechanical mixture. The oxygen and nitrogen in this combination have suffered no change in their secondary properties. They occupy the same space, have the same colour, have the medium weight or density that a mere mechanical mixture of the two should possess. On the other hand, it is observed that oxygen and nitrogen only exhibit the properties of air when they exist in the definite proportion of one to four, and they preserve this proportion on the highest mountains as well as in the lowest valleys. Nitrogen is much lighter than oxygen, yet the oxygen does not separate from the former. This was long held a sufficient proof that the constituent gases did exercise an affinity or chemical attraction for each other sufficient to resist the attraction of gravitation which would make the oxygen descend. An experiment originally made by Dalton, however, demonstrated the fallacy of this opinion, and while it shewed that the gases probably existed in a mere state of mechanical union, led the way to many other most important views in meteorology. It has also, as I shall subsequently shew, been the means of our obtaining more accurate ideas on the function of animal respiration than we otherwise could have formed.

In Dalton's experiment a vessel of hydrogen gas was placed at the *upper* end of a long tube, a vessel of carbonic acid gas at the *lowest* part, and a communication established between them. As hydrogen is the lightest, and carbonic acid one of the heaviest of known gases, and as these have no chemical affinity for each other, it might have been expected that the hydrogen would remain above, the carbonic acid below. But on the contrary in a few hours the light gas had descended, the heavy had risen up, so that in direct opposition to the force of gravity both were equally diffused through each other.

This extraordinary fact was ably followed up by Drs. Faust and Mitchell, of Philadelphia. These experimentalists found that so powerful is the tendency possessed by some gases to diffuse themselves through others, that the interchange takes place through dense membranous bodies, such as bladders or layers of Indian rubber. If a bladder nearly full of common air be placed in a vessel of carbonic acid, the air passes outwards, the acid gas inwards, through the coats of the bladder; and the latter with so much greater power that the bladder soon becomes distended and *burst by the carbonic acid!* Or the experiment may be beautifully shewn by covering with sheet Indian rubber a wide-mouthed glass, one-third full of lime water, and placing it in a jar of carbonic acid. The acid gas quickly penetrates the membrane, and the lime water becomes milky, owing to the precipitation of insoluble carbonate of lime.

These experiments were repeated on a great number of gases, and in every instance were attended with analogous results. The facts thus described, are closely allied to the phenomena which take place when certain liquids of different densities are placed at opposite sides of a membranous partition. To the tendency to pass inwards through the membrane the term *Endosmose,* to the effort to pass outwards that of *Exosmose* has been applied; from Greek words significant of the facts described. The cause of the strange action is as yet obscure; an ingenious attempt has been made by Dutrochet, the discoverer of these actions between liquids, to connect the cause with electric excitement of opposite kinds, but on this interesting topic it would be premature to treat more minutely in this place.

From these experiments, however, we are enabled to comprehend how it is that nitrogen and oxygen remain equally diffused through each other, notwithstanding their different weights. We can hence clearly understand, how the carbonic acid constantly formed at the surface of the earth, is removed so that it does us no injury; and why that heavy gas exists in the same proportion at the summit of the Himalayas as at the level of the sea. We can trace in them a law by which tracts of country, otherwise necessarily pestilential, remain comparatively salubrious, and, on the other hand, they explain to us why the miasms of some diseases of terrestrial origin diffuse themselves through the air even against the force of contrary winds. How closely these experiments bear on the function of respiration I will shew in another section. Meanwhile let us consider some other points in the chemical history of atmospheric air.

COMBUSTION.

The term *combustion* is generally applied to all those phenomena in which heat and light are evolved with the formation of some new product from the substances acted on. Thus wood undergoes combustion in the air, unites with its oxygen and forms carbonic acid; sulphur when burned forms sulphurous acid, phosphorus produces a similar acid, &c. This fact, the *formation of new products*, is the essential feature of combustion, and wherever it occurs with the evolution of heat and light, *combustion* is properly said to have taken place. In this it differs from *ignition*, in which heat and light are evolved without any change, as when lime, platinum, gold, &c. are heated to redness, and undergo no alteration.

The ignition of an elementary body may thus occur in a vacuum; for its combustion, some other substance must be present.

The cause of combustion, or the evolution of heat and light with a change in the properties of the substance acted on, has altogether escaped observation. Not long since it was generally believed that combustibles contained heat, and that oxygen contained light, and that when both united, these elements were set free. This, however, was a mere paraphrase for expressing a fact then and still but little understood. Neither oxygen nor atmospheric air are essential to the process, for combustion occurs in many cases when both are absent. Thus a mixture of iron filings and sulphur, or sulphur and copper, heated together in a glass vessel, from which air is excluded, will suddenly become intensely ignited, heat and light be evolved, and a new product, the sulphuret of iron or copper formed.*

Again, to account for combustion, it having been generally observed, that when bodies increase in density, as when air is compressed or iron is hammered, heat is given out; and as bodies burning in the open air unite with its oxygen which is consequently condensed—from these facts, it was inferred that condensation was the cause of the evolution of heat and light. But a simple experiment is enough to disprove this idea. A grain of gunpowder *expands* on explosion to 250 times its volume, and yet produces intense heat. Electrical action again having been proved to be a powerful heating agent, it was supposed to be the cause of the phenomena of combustion. This theory, however, as yet rests without conclusive proof, although the progress of science is hourly rendering its probability more apparent.

On the whole, we must content ourselves, then, with the mere knowledge of the fact, that intense chemical action frequently gives rise to heat and light. Beyond this at present we cannot go. We shall return to the subject again in subsequent parts of this work, when we shall find that though it may be theoretically barren, it is in practice fraught with the most instructive and useful applications.

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* Powdered bismuth and antimony, copper foil and warm mercury, will burn in chlorine gas—*Class experiments.*

INFLUENCE OF AIR ON VEGETATION.

The reciprocal influence of air and vegetation is a part of this subject, much better understood, than that which we have just discussed. *Germination* is the process by which a new plant originates from seed. A seed consists essentially of two parts,—the *germ* of the future plant, and the *cotyledons*, or seed lobes. It is found, that the cotyledons afford the nourishment essential for the germ, till this becomes sufficiently advanced to draw its materials from other sources. The conditions essential for germination are moisture, a moderately high temperature and the presence of oxygen gas. The latter is so necessary, that no seed will grow or germinate if oxygen be absent.

The chemical changes which take place are chiefly these, the oxygen gas of the air is consumed, and a precisely equal volume of carbonic acid is given out, the carbon being supplied by the seed, which accordingly loses weight in proportion. From the moment the *leaves* of the plant begin to be developed, changes of another kind, and still more interesting, take place. Instead of producing carbonic acid, the plants absorb it from the air and exhale oxygen in return, that is, as long as they are exposed to the direct or diffused light of the sun. If no carbonic acid is present, no oxygen is absorbed. In the dark, however, an opposite change ensues; oxygen, as in the germinating plant, disappears, carbonic acid is again formed. On the whole, however, the balance is in favour of the oxygen, and that it is derived from the carbonic acid inhaled, and its carbon applied to the nourishment of the plant, is proved by several conclusive facts. Thus plants do not thrive in an atmosphere of pure oxygen. On the contrary a little carbonic acid is favourable to their growth, if it does not exceed one-twelfth of the entire. In a larger proportion than this, carbonic acid is prejudicial, and in an atmosphere of equal parts of air and carbonic acid, plants perish,—are poisoned in fact,—in about seven days. When two-thirds of carbonic acid are present, no vegetation occurs.

From some experiments recently made by Mr. Ellis, it was inferred, that although plants evolve oxygen and absorb carbonic acid, under the influence of the direct solar rays, nevertheless the diffused or ordinary daylight has not the same effect. He believed that the same changes proceed by night and day, unless where the plant is directly exposed to the sun. But the question has been completely set at rest by still later experiments by Dr. Daubeny, of Cambridge. He has proved beyond a doubt, that the early doctrines of Priestley are those most deserving of reliance,—that vegetating plants exhale much more oxygen than they consume,—that they absorb carbonic acid, and that these changes take place as well in diffused daylight as by direct exposure to the solar rays.

Several other facts illustrate the mutual agency between the atmosphere and the *vegetable* world. In every step too, we find these phenomena either counterbalancing the deleterious effects which animal exhalations would occasion by the production of carbonic acid, or throwing light upon many of the most mysterious processes of the animal economy. On the whole, the subject is admirably calculated to exhibit in a pleasing aspect the objects of the science we are pursuing. Can any event be more hidden from the ordinary tracing of observation, more remote from the instinctive knowledge of mankind, than that we should be incessantly throwing off from our lungs a poison of great power—or that, in apparent reversal of the laws of nature, and as if for the especial preservation of animal life, a heavy fluid,—carbonic acid,—should diffuse itself through a light one, while the vegetable world lends us in every leaf an antidote against even the remnant of this poison. The delight and admiration which hailed this discovery in Europe, were greater than had ever before been similarly excited. Dr. Priestley's researches were the theme of admiration in all the learned societies of Europe. In 1773 he was presented with the Copley medal of the Royal Society, by the President, Sir John Pringle, who, in addressing Dr. Priestley, made use of the following appropriate language, in describing the discoveries they were met to commemorate and reward: "From these discoveries," Sir J. Pringle said, "we are assured that no vegetable grows in vain, but that from the oak of the forest to the grass of the field, every individual plant is serviceable to mankind, if not always distinguishable by some private virtue, yet making a part of the whole which cleanses and purifies our atmosphere. In this the fragrant rose, and deadly night-shade co-operate. Nor is the herbage nor the woods that flourish in the most remote and unpeopled regions unprofitable to us, nor we to them, considering how constantly the winds convey to them our vitiated air for our relief and for their nourishment. And if ever," Sir John Pringle continued, "these salutary gales rise to storms and hurricanes, we still can trace the ways of a provident power, which not fortuitously but with design, not in wrath but in mercy, thus agitates the water and the air together, to bury in the deep those pestilential effluvia which the vegetables on the face of the earth had been insufficient to consume."

RESPIRATION AND ANIMAL HEAT.

The next subject for our study is the respiration of animals, and the connexion of animal heat with chemical as well as vital operations.

Respiration, or in ordinary language, breathing, is a function essential to the existence of all the higher animals. Anatomical and chemical researches have further shewn that in various modifications the function is equally necessary to all classes of living things, whether animal or vegetable. Indeed neither vegetable nor animal can maintain existence for the ordinary period of life, where the breathing of atmospheric air cannot be carried on. By means of an air-pump we can withdraw the air from a certain space; within that all the higher animals immediately perish; and those lower in the scale of creation, though they do not instantly die, nevertheless, have their period of life greatly shortened. Nay, more, the breathing of air is found essential even to those animals which inhabit water. They must either rise to its surface to respire, or they are furnished with contrivances for separating from the water the air it always contains. That water in its ordinary state contains air, is proved by placing it under the receiver of an air-pump, which quickly causes its extrication, and if in this experiment a fish were placed under the receiver, it would be found to die when the air was totally withdrawn.

The maintenance of life by fœtal animals still in their mother's womb, might at first sight be deemed an unanswerable contradiction of this asserted necessity of respiration. But on investigating the true nature of the function, the difficulty is at once overcome. The essential fact in respiration is not the mere drawing in of air by the mouth or similar apertures. The exposure of the blood to air is the only necessary part of the process, and accordingly we find, that however this is accomplished, whether in the lungs of the higher animals, in the gills of the fish, in the air-canals or trachea of insects, the same effect is produced. The blood of the fœtus is thus exposed to the air in the lungs of its mother from whose circulation it is derived. The only circumstance necessary for respiration, then, is exposure of blood to the air. We thus, in point of fact, respire as well by our skins as by our lungs; nay more, in some amphibious animals, as Geoffroy St. Hilaire has lately shewn, the function is occasionally carried on by the peritoneum. Dr. Goodeve's dissections prove the pouch of the Adjutant bird to be similarly employed; and I have shewn myself, that under certain circumstances the mucous membrane of the intestines of man, and many other Mammalia, carries on the same process.

Let us now see what are the changes, if any, this respiration, or exposure of the blood to air, produces in either of these fluids. The student has now. learned the composition of the air, and can consequently judge of any alterations the blood may effect in it, but he must also know something of the nature of the blood, in order to understand their mutual action.

COMPOSITION OF THE BLOOD.

The blood which circulates in the body, varies in its appearance and composition, according as it is drawn from the venous or arterial division of the circulation. Drawn from the veins, as in ordinary bleeding for medical purposes, before exposure to the air, it is of a purple colour inclined to red, of sp. gr. 100.5, its temperature about 98°. When first drawn it seems a uniform red fluid, but when allowed to stand for some time, closer examination shews, that it is essentially composed of two parts,—a transparent colourless fluid called *serum*, and of *solid* minute particles termed *globules*.

The serum is a complex substance, containing several matters easily separated from it. The globules, on the other hand, are of a spherical shape in man, but elliptical in birds, and in all the higher animals are composed of an envelope of colouring matter round a colourless solid nucleus of a substance called *fibrine.*

In the living animal during health, the blood is fluid as long as life remains, but when the influence of the vital power, whatever that be, is withdrawn, the blood soon loses its fluidity, or coagulates, as the change is termed. Thus when drawn from a healthy person and set to rest, it separates into two parts, one fluid and colourless, termed *serum*, the other a red clot of uniform colour termed *crassamentum*, which contains all the red globules, or insoluble parts of the blood. The proportion of crassamentum to serum is very variable, and dependent on the circumstances under which the blood is drawn.

On analysis the *serum* is found to contain water 88, albumen 8, oily and saline matters about 4 per cent. The albumen is an animal progimate principle, described more minutely under the head of "Animal Chemistry." It is a substance nearly identical in composition with the "white" of eggs.

The *crassamentum* yields on anaylsis a red colouring principle and a substance named *fibrine*, which is also fully described in another section. This is the portion of the blood which coagulates or solidifies, and it is also the basis of animal fibre or flesh. Besides these principles, the crassamentum is mechanically mixed with serum retained in the interstices of the spongy mass formed by the coagulated fibrine.

From these data the venous blood is inferred to consist of, in 1000 parts.

Water,	780
Fibrine,	3
Colouring matter,	133
Albumen,	65
Oily and Fatty matter,	3
Saline and earthy matter, with traces of iron,	10

I have also satisfied myself of the existence in blood of another animal principle not previously described,* but until my

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* See Transactions of Medical Society of Calcutta, for 1834.

experiments are corroborated by other chemists, I am not entitled to introduce the principle into the preceding table, in a work intended merely for elementary instruction.

With the preceding ingredients others are often found, as in cholera *urea*, the proximate and characteristic principle of urine; in jaundice the peculiar colouring matter of the bile. But there is also invariably present in venous blood a considerable proportion of dissolved carbonic acid gas.

This is the chief, if not the essential difference between arterial and venous blood. It is true they differ in colour; the blood from the arteries being florid, and from the veins black, or deep purple; but so many circumstances seem to influence the change of tint, that this is not entitled to be regarded in the important light in which it generally is viewed. Thus various saline matters, such as common salt, sugar, urea, &c. turn black blood to red, without exercising any important influence on its composition or properties. The chief difference I repeat, is the presence of carbonic acid in the venous, and its absence in the arterial blood. Generally these different kinds of blood differ in colour, as I have said before, the arterial being florid, and the venous purple, and this it is essential to bear in mind, as a guide in many surgical operations. But little importance, however, is to be attached to it with reference to the physiology of respiration, or the mutual agency of the blood and air, since it is frequently found that venous blood is as florid as arterial, while many animals have blood of various colours, such as blue, or green, or white, or altogether colourless. But in these creatures the essential phenomena of respiration go on as completely as where the most marked difference between the red and purple is noticed.

We have now sufficiently studied the composition of the blood to enable us to understand the changes which take place when in the *venous* state it is mixed with or exposed to the air.

In the first place the colour changes from purple to red;—secondly, oxygen gas disappears;—thirdly, carbonic acid is generated. The first of these, though the more manifest, is for many reasons the least important of the entire.

Arterial blood on exposure undergoes none of these changes, neither is the air affected.

The influence of the air on the blood is therefore limited, as far as we have the means of judging, to the venous fluid.

I have said that venous blood when mixed with air absorbs oxygen and gives out carbonic acid gas. This, until very recently, was supposed a sufficient proof that the venous blood contained *carbon* in a free or uncombined state; that this carbon united with the oxygen of the air, &c. But this opinion has been shewn to be gratuitous by the recent discoveries of the existence of carbonic acid in the venous blood —of the permeability of membranes, and the interchange which takes place through these of various gases destitute of affinity for each other. We said that when air was contained in a vessel covered with an organic membrane, carbonic acid from the other side rapidly passed through it. This is apparently what occurs with the blood circulating through our lungs, the carbonic acid it contains being exchanged for oxygen derived from the atmospheric air. It has been objected to this view, that in some admirable experiments lately made by Dr. Christison, the quantity of oxygen absorbed was found to vary in an inverse proportion, according to the amount of colouring matter present in the blood, and the degree of redness of its colour. Thus very dark blood containing much colouring matter was found to absorb more oxygen and give off more carbonic acid than comparatively florid blood, though both were drawn from the veins. But the objection is readily answered—the darker the colour, the more carbonic acid does the blood contain, and the more it must exchange with the air; and the lighter the colour, the less the carbonic acid, and the amount of the interchange will be proportionately small.

Assuming then on the strong facts I have adduced, that the interchange of oxygen and carbonic acid occurs in the mode I have described, there still remain some very important points for examination.

The first is the proportion of oxygen consumed, and of carbonic acid evolved, in the respiratory process. The most conclusive experiments on this subject are those by Dr. Edwards, who succeeded in this, as in many other remarkable controversies, in reconciling perfectly the apparently contradictory statements of other experimentalists. Some, for instance, contended there is more oxygen consumed than carbonic acid evolved—others, the very reverse. Edwards, by a masterly series of experiments, proved satisfactorily the true nature of the process. In some animals the ratio is equal, in others the loss of oxygen exceeds the production of carbonic acid, while in man the consumption of oxygen is generally somewhat greater than the production of carbonic acid.

The quantity, moreover, is variable in different individuals, and in the same person at different times. In some well-conducted experiments, twenty-six cubic inches of carbonic acid were exhaled, and the same quantity of oxygen consumed, per minute; an estimate, however, which I believe, to be rather too great. It has been shewn beyond a doubt too, that more carbonic acid is given off by day than by night; most at noon, and least at sunset. In each expiration it is quite certain that three per cent. of carbonic acid are returned with the air inspired.

We have now examined the circumstances connected with the mutual action of blood, carbonic acid, and the oxygen of the air; it next remains to inquire how, if at all, the *nitrogen* is affected.

The only trust-worthy experiments on this subject are some very recently made by Dr. Edwards, who found and proved beyond a doubt, that in every animal experimented on, the volume of nitrogen in a given proportion of air was increased during summer, and diminished through the whole of winter and beginning of spring. Again, in two remarkable experiments of Allen and Pepys, two animals were confined, one in oxygen and the other in a mixture of 20 parts oxygen, and 80 parts HYDROGEN, and each gave off *more than their own bulk of Nitrogen gas.*

These facts prove, indisputably, that nitrogen may be absorbed, retained in the animal economy, applied to its uses, and again re-secreted and discharged by expiration; and they furnish a clue which enables us to comprehend many circumstances in physiology and pathology, which would otherwise prove altogether inexplicable. The mere fact, however, that animals can secrete a quantity of nitrogen greater than their own bulk, is not at all more wonderful than a thousand analogous occurrences which daily present themselves to our notice. In certain disordered states of the digestive canal various gases, such as nitrogen, carburetted hydrogen, and sulphuretted hydrogen, are generated in immense quantities, and discharged by eructation. In the disease termed tympanitis, a prodigious volume of gaseous matter is similarly and suddenly evolved. In the tribe of fishes, again, we find a gland in the air-bag expressly devoted to the *secretion* of *oxygen* or *carbonic acid,* to enable the animal to swim. In short, these, and a multitude of similar facts might have induced physiologists to spare themselves the pains they have taken so long in discussing the possibility or impossibility of the absorption and exhalation of nitrogen gas. The question is now completely decided.

I have now gone over, as succinctly as practicable, the standard and proved opinions relative to this important function. There are many other theories which I have not touched on, partly from their worthlessness, and partly from their abstruse and unintelligible character.

ANIMAL HEAT.

The few facts which connect the subject of animal heat with the history of atmospheric air, must occupy us but a short time, until we have studied the laws which regulate heat in inanimate objects; moreover, even to the more advanced student the subject is one of the utmost difficulty. To every reflecting individual it must seem a subject of the strangest and most interesting kind that man and the higher classes of living beings should be endowed with the power of maintaining their temperature at a uniform rate; their bodies if duly covered remaining at the same degree of warmth, whether exposed to the rigors of winter in its severest cold, or to the fiercest heat of the tropic zone. Accordingly the subject has been a favourite theme of investigation to natural philosophers for ages, and they have, at all events, accumulated many extraordinary facts bearing on the question, although they may have failed to a great degree in giving it a satisfactory explanation.

Two opposite circumstances may well seem to demand elucidation. In the one instance we find animals inhabiting a cold or temperate climate, where the thermometer frequently falls far below the freezing point, and seldom rises above 80; under such circumstances, I repeat, we find man and the higher animals having a constant heat of from 96 to 98, many degrees above the surrounding atmosphere. Again, in India, where the thermometer often ranges as high as 110 in the shade, the human body and that of the higher animals still remain at the standard degree.

Now, as oxygen gas disappears during respiration, and carbonic acid is evolved, the earlier pneumatic chemists inferred, that as carbon when undergoing combustion evolves heat, the same action in the human body must give rise to a similar result, and that the process of respiration is thus the source of animal heat. This view was strengthened by the facts, that in all animals in which the organs of respiration are small, and which consume but a small quantity of oxygen, the temperature of the body, as in most fishes, rises or falls with that of the fluid in which they dwell. Birds, on the other hand, have very large lungs, and by a peculiar structure respiration takes place in many other parts of the body, and in these the heat is comparatively very high. But the experiments of Edwards shew the strongest proof of the connexion of the function of respiration with the evolution of heat. He found that kittens and puppies soon after birth required but a very minute proportion of oxygen for the support of life. They might be deprived of this gas altogether for twenty minutes, *but they lost heat rapidly on exposure to the air.* But as they grew older, and acquired the power of keeping up their own heat, the power of living without oxygen ceased.

These, and many other facts seemed to prove that respiration, and the production of heat should be regarded as cause and effect. But as the lungs are the organs of respiration, physiologists and chemists hastened to the conclusion, that the oxygen of the air united with carbon *in the lungs;* that carbonic acid was there formed and heat produced; and that the carbon was given by the *venous* blood, which became *arterial* in consequence of the change.

But in opposition to this very ingenious theory, (better known as Dr. Crawford's,) there are these strong facts: first, that the *lungs*, where the supposed changes are going on, are not warmer than the rest of the body; secondly, that the exclusive union of oxygen and carbon in the lungs is a gratuitous assertion, and one rendered improbable by the proved fact, that carbonic acid exists already formed in the venous blood in all parts of the body.

Considerable interest was some years since excited by experiments made by Mr. Brodie, who attempted to prove that respiration had no influence whatever on the production of heat. He killed animals by strong poisons, and when they were apparently dead, he inflated the lungs, and thus carried on an artificial respiration. He stated that oxygen was consumed and carbonic acid formed as in life, but that the temperature *rapidly fell,* as quickly indeed as when no artificial respiration was practised. But later, and perhaps more exact experimentalists have found that the artificial inflation when properly performed *does retard* the cooling, in direct contradiction to what Brodie states; and they thus point to an inference directly opposite to that deduced by Brodie from his experiments.

The fact just mentioned is a very important one. If the artificial respiration retarded cooling, the necessary inference is that it generated heat, for as a merely inert physical agent it would have tended by contact to carry off the heat of the air-cells of the lungs. It thus establishes respiration in the living body as *one* at least of the heat-producing causes. How respiration produces the heat is another question, and one perhaps not so easily settled.

There is, at all events, one truth ascertained beyond a doubt,—that whenever carbonic acid is generated by chemical action from direct union of its elements, heat is evolved. Now that carbonic acid is produced *in the circulation* is clearly proved, and that it is exchanged for oxygen in the lungs is equally certain. I believe the action to go forward in this manner. When the carbonic acid in the veins and the oxygen of the air meet in the lungs, they mutually change places. The oxygen enters the arterial part of the circulation, and is carried in its course in every direction to take part in the changes perpetually occurring in the frame-work of our system. New parts are to be constructed; old and deteriorated particles to be removed. The oxygen effects this. With the hydrogen and carbon it forms water and carbonic acid, which return by the veins; and it is well worth recollection here, that analysis has shewn the venous to contain more water than the arterial blood. Heat is necessarily evolved, and as these changes occur all over the frame, this heat must be generally diffused. According to these views most of the difficulties are obviated as to one source of the production of heat, and its maintenance by living animals in air colder than their bodies. It has been stated that the change of venous into arterial blood cannot solely maintain the heat of animals, because all the carbonic acid evolved from their lungs would not account for the heat they can communicate to surrounding bodies. But this objection overlooks the great quantity of the carbonic acid exhaled from the skin and evolved in the intestines, and it neglects the obvious production of water in the system. The elements of water we know are oxygen and hydrogen. Accurate experiments prove that the watery exhalations from the lungs, the perspiration from the skin, and the urinary secretion, considerably exceed the daily amount of water we consume. Whence then do these watery secretions originate? Certainly from the oxygen inspired from the air, and hydrogen contained in our solid and liquid food. That the union of these elements must occasion the evolution of heat, seems altogether beyond contradiction.

One very interesting analogous fact bears so strongly on this question, that I cannot avoid bringing it to the student's observation. It is a palpable instance of a chemical change producing heat in a living tissue. There are several flowers which at the period of developing the seed-vessel, absorb oxygen from the air and evolve carbonic acid, and in doing so their heat increases several degrees. In one experiment performed at the Mauritius on a plant called the *Arum cordifolium*, the thermometer stood 57 degrees higher in the flower of the plant than in the air. The flower of the Indian gourd in twenty-four hours consumes seven times its volume of oxygen, and the heat is increased eight degrees.

If then a living vegetable can, by the union of its carbon with the oxygen of the air, produce so many degrees of heat, and if oxygen and carbon unite in the animal circulation, are not the same results to be expected in the living animal? Now besides this known combination of carbon and oxygen, I have shewn an additional source of heat in the chemical union of the inspired oxygen with hydrogen to form water. Over all these changes it is true that in the living body there presides a power to the nature of which we are as yet total strangers, and which unquestionably works with a subtlety, of which our most delicate experiments can give but a rude and imperfect imitation. But we should remember too that however mysterious these things appear, they are not more so than many matters of recent discovery were but a few years ago. In one department especially—that of Electricity,—one, too, which bears closely on that we are now examining, discoveries are hourly making, which bid fair to unravel many functions of the animal body, hitherto deemed altogether beyond research.

The production of animal heat and its maintenance *above* that of surrounding media, as far as these subjects may be elucidated by chemical illustration, is all I can advert to here. How the body maintains a *lower* temperature, can only be understood by those conversant with the physical laws of heat and evaporation.

I shall now proceed to give a brief outline of the physical properties of the atmosphere, the chemical and physiological qualities of which we have now discussed.

PHYSICAL PROPERTIES OF THE ATMOSPHERE, ITS WEIGHT, ELASTICITY, AND PRESSURE.

In conclusion of our sketch of the history of atmospheric air, it is desirable to offer a succinct account of some phenomena dependent on the material properties of this fluid.

Astronomical calculations have shewn that the height of the atmosphere is about 45 miles above the level of the sea. Now 100 cubic inches of air at that level weigh over 31 grains, and the total weight of a column of the atmosphere one inch square is easily proved to be about 15 lbs.; consequently, the air which surrounds this globe is pressing on its surface, and in all directions with a force of 15 lbs. to the square inch.

But air, in common with all elastic fluids, is compressible to a great degree, and consequently when 100 cubic inches are weighed at the level of the sea, they weigh much more than the same measure taken at a great elevation. As the superjacent column diminishes in length, the lower portions are relieved from pressure. These consequently expand, becoming specifically lighter, and this is found to occur in a definite ratio to the height. At the height of 15,000 feet, air is very nearly one-half as heavy as at the level of the sea, or on the plains of Bengal; that is, if 100 cubic inches of air from the plains were brought to that height on the Himálayan mountains, they would expand to 200; or if, reversing the experiment, 100 cubic inches were removed from the mountain atmosphere, they would contract to 50 when they reached the plains. This diminution of density goes on in a geometrical ratio; that is, at 30,000 feet the density is one-fourth, —at 45,000 feet, one-eighth of the same bulk at the sea.

In estimating the comparative weights of various gases, atmospheric air is considered the standard. It is occasionally necessary also to compare with this the specific gravities of several liquid substances. Thus water is 815 times, mercury 11,065 times, heavier than air; and, therefore, were we to require columns of equal base, each 15 lbs. weight, of these three bodies, the pillar of air would be the total depth of the atmosphere, that of water would measure 34 feet, that of mercury 30 inches. As the laws of Hydraulics, or of fluids in motion, will clearly explain, these three columns of different materials, all exercise pressure in the same manner, and in all directions.

Thus, if we construct a tube of glass over 30 inches long, closed at one end—if we fill this tube with mercury, and invert it so that the open end may rest in a vessel of that metal, the mercury will stand in the tube very nearly at the height of 30 inches;—and if the tube be 33 or more inches long, three inches or more of *empty space*, or *vacuum* will occur between the upper surface of the mercurial column and the closed extremity of the tube. A little reflection will explain the cause of these phenomena. The atmosphere in consequence of its weight presses on the vessel of mercury with a force equal to 15 lbs. on the square inch of surface. The mercurial column having the same proportionate weight, descends no lower, and will remain no higher. Were we to employ a tube 60 inches long, the pillar of mercury would be 30 inches, and the vacuum or free space occur to the extent of the remaining 30 of the glass tube.

A tube of this description is named a Barometer. It was invented by Toricelli in the seventeenth century. As the depth of the atmosphere decreases at high elevations of the globe, if provided with a Barometer we ascend a mountain, the column of mercury shortens as we proceed; and at 15,000 feet—at the summit of Mont Blanc, for instance, where the density of the air is about one-half—the Barometer stands at 15 inches, or one-half of the balance of the atmosphere at the level of the sea. And on the contrary, if we descend into a deep mine, the mercury rises in the Barometer, shewing that the balancing column of the atmosphere is increasing in weight.

But there are many circumstances which, exclusively of the atmospheric pressure itself, affect the length of the mercurial column. As all liquids and solids expand by heat, the mercury lengthens to a sensible degree as the temperature of the atmosphere increases, but as the glass tube enlarges laterally to nearly the same extent, this circumstance does not very materially complicate the indications regarding atmospheric pressure which the Barometer supplies.

But the varying amount of *watery vapour* in the total depth of the atmosphere, and actually dissolved in the air, influences the Barometer in a remarkable degree. Instruments have, however, been constructed which indicate with great precision the quantity of watery vapour present in a given bulk of air, and thus enable us to ascertain the actual amount of pressure dependent on the air itself, apart from the vapour with which it is impregnated.*

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* A description of Daniell's Hygrometer, with tables for its use, is given in the Appendix.

SECTION VII.

CHLORINE, ITS COMPOUNDS WITH HYDROGEN, OXYGEN, NITROGEN, AND CARBON.

Chlorine, the last of the simple gases, was discovered in 1774, and erroneously regarded as a compound of oxygen and muriatic acid until 1809, when the researches of Sir Humphrey Davy and Gay Lussac established its right to be considered an elementary substance.

Chlorine does not exist in nature in a free or uncombined state, but its compounds are extremely numerous—of these the most important is common salt, the *chloride of sodium*, in which one equivalent of the gas and one equivalent of a metal unite to form the white crystalline salt, so indispensable to mankind.

The composition of common salt, or, as I shall subsequently call it, the chloride of sodium, is proved by various experiments, of which the simplest and most conclusive is the effect of the Galvanic Battery. If the conductors of an active series of plates be brought in contact with a portion of chloride of sodium, while melted by heat, *chlorine* appears at one pole, the positive or anode conductor,—and brilliant globules of the metal sodium are formed at the cathode or negative side. The combining proportion of chlorine in this, as in all its other and numerous compounds, is 35, 42.

The gas thus extricated possesses very remarkable properties. It is of a greenish yellow colour, from which it derives its name. It is extremely irritating and corrosive, and consequently irrespirable. It is absorbed by cold water, from which it is evolved again by the immediate application of heat—but if the chlorine remains long in contact with water, it unites with the hydrogen of this liquid and sets its oxygen free—changes which are much accelerated by exposing the mixture to the rays of the sun.

Chlorine supports the combustion of several burning bodies. Phosphorus in large pieces, antimony, copper, zinc, and bismuth in powder or fine leaves, inflame in it at once; and mercury, if previously heated, quickly exhibits the same phenomena. In all these instances a binary or double compound of chlorine and the second element is produced. For hydrogen chlorine possesses such a powerful attraction that it decomposes water, as before stated. It inflames pure oil of turpentine, a liquid compound of carbon and hydrogen. Mixed with hydrogen in equal volumes it detonates when in contact with an electric spark, an ignited wire, with flame, spongy platinum, or on exposure to the sun's rays.

But of all its properties, perhaps the most remarkable is its bleaching power. It destroys at once all animal and vegetable colours, and this by careful management can be accomplished without difficulty, and without injuring in the least degree the fabric of the material on which the process is performed. Hence in the bleaching of linens, calicos, and woollen cloths, for the purposes of the manufacturer, and to prepare these textures for the admirable processes of the dyer, enormous quantities of chlorine are now manufactured in Europe. The bleaching powers of chlorine are well observed on a small scale by introducing flowers or grass into a bottle of the gas.

Besides these valuable qualities, it also destroys effectually the volatile products of decaying vegetable or animal matter, and thus deprives it of its disgusting smell. Hence in the fumigation of ships, hospitals, and prisons, in anatomical theatres, &c. its application is equally useful and extensive. For all the preceding purposes the chlorine is practically used in combination with soda or lime; preparations I shall describe in another section.

From the foregoing sketch the student can understand the experiments I shall now describe for the preparation, collection, and examination of the properties of the gas.

Muriatic acid, or the hydro-chloric, as it is more properly designated, is composed of hydrogen 1 eq. and chlorine 1 eq. dissolved in a variable proportion of water. Now by mixing in a glass retort hydro-chloric acid with half its weight of powdered peroxide of manganese, (see page 22,) the oxygen of the peroxide and the hydrogen of the hydro-chloric acid unite to form water, and chlorine is liberated with effervescence on the application of a gentle heat. It should be collected over salt water, in bottles filled with salt water also, and provided with close-fitting stoppers, which should be rubbed with a little oil.

In this process, 2 equivalents of hydro-chloric acid—chlorine, eq. 35 × 2 = 70, and 2 hydrogen, eq. 1 = 2, are decomposed by 1 eq. of peroxide of manganese—manganese 1 eq. 27, oxygen 2 eq. 16. The results are, chloride of manganese 1 eq. (chlorine 35, manganese 27;) water 2 eq. (hydrogen 2, water 16,) and chlorine 1 eq. 35.*

For use on the large scale, another and more economical process is employed. Three parts of chloride of sodium, (common salt) are mixed with one of peroxide of manganese, two of sulphuric acid, and three water. The reaction is complex, but easily intelligible, and affords a good lesson in the study of decomposition.

The changes may be regarded as occurring in three stages—

1st. The moment the chloride of sodium is dissolved in the water that fluid is decomposed; its oxygen with the sodium forms *soda;* its hydrogen with the chlorine, *hydro-chloric* or muriatic acid; and the soda and acid may be considered as a muriate of soda, or hydro-chlorate, as they are indiscriminately named.

2nd. The sulphuric acid unites with the soda, setting free its muriatic acid; it acts also on the peroxide, of manganese, uniting with its protoxide and separating 1 equivalent of oxygen—a sulphate of soda and proto-sulphate of manganese being formed.

3rd. The liberated hydro-chloric acid and oxygen react on

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* The fractions are designedly omitted to simplify the calculation.

each other. The oxygen with the hydrogen of the acid forms water, and chlorine is disengaged.

As sulphuric acid is manufactured and sold at one penny the pound, peroxide of manganese sold at two pence the pound, and salt cheaper still; and as the resulting sulphates of soda and manganese meet a ready market, this process affords chlorine at an extremely low price.

100 cubic inches of chlorine weigh about 76 grains. Its specific gravity is consequently 2.47.

Chlorine unites directly with all the simple substances, the metals included. It also combines with several oxides. With some of these its reaction is very peculiar and important; the more so, as similar changes occur with the analogous elements, bromine, iodine, and others.

Thus when the oxides of potassium, (potash) sodium, (soda) calcium, (lime) barium, (baryta) are heated with chlorine in water, the water is decomposed; its oxygen with chlorine forms chloric acid; its hydrogen, with another portion of chlorine, forms hydro-chloric acid; and lastly, both these acids combine with the oxides to form neutral salts. I would impress on the student the necessity of attending closely to the changes here described, for he will find them to afford a key to many chemical changes otherwise very difficult to understand.

I shall now describe the compounds which chlorine forms with hydrogen, oxygen, carbon, and nitrogen, the simple substances which we have already gone over.

HYDRO-CHLORIC, OR MURIATIC ACID.

A solution of this gas in water was discovered by Glauber in the course of the seventeenth century, and the gas itself was separated and its properties studied by Dr. Priestley in 1772. It is prepared by acting on chloride of sodium with concentrated sulphuric acid. One eq. of the water of the acid is decomposed; its hydrogen with the chlorine forms muriatic acid gas, which is set free; its oxygen with the sodium forms soda; and this lastly, with the sulphuric acid forms the sulphate of soda. The gas evolved being much heavier than atmospheric air, may be collected in bottles in the mode described in the section "Carbonic Acid." It cannot be procured by the water-bath, for muriatic acid gas is absorbed instantaneously by that fluid.

There are many other methods of preparing this gas. By heating the strong muriatic acid of commerce, all its gas is expelled and its water remains—or by subjecting a mixture of equal volumes of chlorine and hydrogen to flame or the electric spark, or by exposure to the sun's rays, detonation ensues, and the acid is immediately formed.

Muriatic acid gas is colourless, very acid to the taste, and pungent to the smell. It is quite irrespirable, is not combustible, and does not support combustion in other bodies. It is powerfully acid, and reddens permanently vegetable blue colours. Its affinity for water is very great. One cubic inch of water absorbs 418 cubic inches of this gas, and expands one-third in volume. A very beautiful experiment shewing the force of this attraction, may be made by filling with the gas a large bottle provided with a cork and narrow tube. On inverting the bottle in a vessel of water tinged with some blue vegetable fluid, (red cabbage boiled in water answers perfectly)* the water springs like a fountain through the aperture, and the acid at the same time acting on the blue fluid changes it to a lively red colour.

* Or the flowers of the Jaba, *Hibiscus rosa sinensis.*

By passing a current of this gas through water, as long as any is absorbed, we obtain a concentrated solution much used in pharmacy and in the arts, described by the older writers as "Spirit of sea salt," by modern authors as muriatic or hydro-chloric acid. With Woolfe's bottles, a large quantity of this acid may be prepared without difficulty. Where that apparatus cannot be obtained, the following cheap and simple substitute will be found to answer effectually.

One of the green glass-bottles of two or three quarts capacity (made and sold in the bazars, especially at Gházipur), for holding rose water, fitted with a waxed cork and bent glass tube, makes an excellent retort. The tube should be led through a cork into a wide-mouthed bottle containing a little water, and also about half an inch deep of mercury, under the surface of which the tube should dip. A second tube from this bottle is led through a cork into a larger bottle, in the mode delineated in *fig.* 18 where three bottles are shewn thus connected. Now, on introducing equal weights of salt, water, and sulphuric acid, and applying heat by a sand-bath, such as previously described, the acid gas is disengaged, generally associated with traces of a volatile compound of iron, and also with some nitrous acid originally contained in impurities in the salt. The gases rise through the mercury, and, meeting the water, are instantaneously absorbed; were the mercury not interposed, the water would rush back into the retort, probably break the vessel, and at all events spoil the experiment. The impurities alluded to are dissolved in the water in the first bottle, with as much muriatic acid gas as it will take up. As soon as it is saturated the gas then passes into the second bottle, where a pure acid solution is formed.

This solution is a colourless liquid, of specific gravity 1.170, and gives out dense vapours when exposed to the air. It boils at 110°, evolving large quantities of pure acid gas.

This solution is easily decomposed by the Galvanic Battery; chlorine appearing at the anode, hydrogen at the cathode. Many substances containing large quantities of oxygen also effect its decomposition; thus nitric acid, the peroxides of manganese, lead, &c. combine with its hydrogen and set the chlorine free. Thus, if nitric acid be mixed with muriatic acid, chlorine is set free, as is shewn by the liquid dissolving gold or platinum—metals insoluble either in the muriatic or nitric acids alone, but which are speedily dissolved by chlorine.

A remarkable effect takes place when muriatic acid is added to a solution of the oxide of silver, in nitric or any other acid; the chlorine unites with the silver, forming a white solid precipitate, the chloride of silver, which is insoluble in water, or acids, and is dissolved by liquid ammonia. This property of chlorine enables us to detect and measure the smallest quantities of muriatic acid in nitric acid, or any other compound with which it may be mixed. As the equivalent number of silver is 108, and of chlorine 35.42, when the precipitated chloride of silver is dried, its weight indicates exactly the quantity of chlorine, and consequently of muriatic acid present in the tested liquid—(see "*Nitric Acid,*" page 46.) Directions for preparing the nitrate of the oxide of silver are given under the head of that metal. The strength of the muriatic acid solution is ascertained by the proportion of marble, (carbonate of lime) a given quantity of it will dissolve; every 50 grains of marble correspond to 36.42, or 1 equivalent of acid.

OXIDES OF CHLORINE.

These compounds are four in number; namely—

Hypochlorous acid, = Cl. + O. = 35,42 + 8 = 43,42
Chlorous acid, ... = Cl. + 4O. = 35,42 + 32 = 67,42
Chloric acid, ... = Cl. + 5O. = 35,42 + 40 = 75,42
Perchloric acid, ... = Cl. + 7O. = 35,42 + 56 = 91,42

Hypochlorous acid is prepared by diffusing red oxide of mercury through water, and agitating this in bottles filled with chlorine—Oxy-chloride of mercury subsides, and Hypochlorous acid is dissolved.

Properties. Of yellow colour, bleaches powerfully and oxidizes with great energy. By absorbing the water by nitrate of lime it is obtained in the gaseous state, and is eminently explosive. It combines with bases and forms valuable bleaching salts.

Chlorous acid is prepared from the salt called chlorate of potassa, by reducing it to powder and adding sulphuric acid. Very small quantities of the materials should be used—not more than 30 or 40 grains of the salt, and the experiment performed in a test tube of strong glass, tied to the end of a stick two or three feet long. By immersing the sealed end of the tube in warm water a yellowish green gas is disengaged.

The most characteristic property of this gas is the facility and violence with which it explodes. If the water be heated to the boiling point, or the flame of a spirit lamp applied, a loud detonation occurs, and the tube is generally shattered to pieces.

This gas has been subjected to minute study by several eminent chemists, but as it possesses no useful qualities, I shall not dwell on it in more detail.*

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* By dropping a few crystals of chlorate of potash and shreds of phosphorus into a champagne glass filled with water, and then introducing a little strong sulphuric acid through a long tube, chlorous acid is set free and inflames the phosphorus under water.

The *Chloric acid* is important only owing to the interesting salt it forms with the oxide of potassium, potash.

When a solution of this alkali is saturated with chlorine gas, in a Woolfe's apparatus, and the liquid gently heated, the water is decomposed, and muriate and chlorate of potash formed in the manner described at page 90. The chlorate of potassa being much less soluble in water than the muriate, is deposited in tabular crystals of a pearly lustre, and may be separated by filtration.* It is composed of chlorine 1 eq. potassium 1 eq., oxygen 6 eq. When heated till it melts, it is totally decomposed, the whole of its oxygen being disengaged in the gaseous state, and a white crystalline compound, the chloride of potassium, left behind. This experiment can be performed in a green glass flask or retort; 122 grains of the chlorate yield 48 grains or 161 cubic inches of the purest oxygen gas which can be procured.

Owing to the great quantity of oxygen which the salt contains, it forms with combustible bodies a number of violently detonating compounds. A grain or two rubbed in a mortar with an equal quantity of sulphur gives a series of sharp explosions. Mixed with sugar or turpentine and touched with a drop of sulphuric acid, the mixture bursts into a flame, and on this principle the "instantaneous light" apparatus is constructed, the matches being tipped with a paste of chlorate of potash and sugar, which inflames on being immersed in a phial of sulphuric acid.

Perchloric acid. In the process for preparing chlorous acid from chlorate of potash and sulphuric acid, the salt is decomposed by the sulphuric acid, and its chloric acid set free. At the moment of its liberation this acid is itself resolved into peroxide of chlorine and oxygen. The former is disengaged, the latter with some undecomposed chlorate of potash forms a perchlorate of that base. This salt being with difficulty so-

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* For directions for the performance of filtering and similar manipulations, see *Appendix.*

luble in water, is separated readily from the sulphate of potassa formed at the same time.

From this salt the perchloric acid can be separated by means of strong sulphuric acid. It may be obtained in the crystalline state, but generally occurs as a dense liquid. Its properties are not sufficiently important to deserve more minute description here.

Two other compounds of chlorine and oxygen have been enumerated by writers on chemistry. The first, or Euchlorine, as it has been called, has very recently been proved to be a compound of chlorine and chlorous acid. The second or the *chlorous* acid is identical with the peroxide of chlorine of our first edition.

CHLORIDES OF CARBON.

Four compounds of this kind have been discovered: only one, the Perchloride, is of sufficient interest to the student to demand a particular notice; and as its preparation depends on that of carburetted hydrogen, a gas I have not yet described, I must defer its consideration to that head.

CHLORIDE OF NITROGEN.

There is very little difficulty in the preparation of this, perhaps, the most dangerous compound the chemist can produce.

If an ounce of nitrate of ammonia (see page 35) be dissolved in twelve ounces of warm water, (100° Fahrt.) and a wide-mouthed glass bottle, full of chlorine, inverted over it; in about a quarter of an hour the gas disappears, and numerous globules of a dense yellow, oily-looking fluid collect on the solution, and gradually fall through it to the bottom of the vessel, where they should be received on a small leaden cup. When a drop, the size of a pea, has formed, the process should be discontinued. This substance is the quadro-chloride of nitrogen (4 chlorine, 1 nitrogen). It is distinguished by its extraordinary explosive properties. If heated to 212, it at once detonates with a loud report, and if touched with olive oil, or any other greasy substance, a violent explosion takes place.

This singular substance nearly proved fatal to its discoverer Dulong, and to Sir Humphrey Davy, who courageously and successfully undertook its analysis. Whoever ventures on repeating the very easy experiment should be careful that the glass vessels should be free from any greasy or oily marks, as the least particle of this kind will inevitably explode the chloride of nitrogen as soon as it is formed.

SECTION VIII.

SULPHUR AND ITS OXIDES.

Sulphur, the گندك *(gandak)* of the Hindus, is a well known and most abundant natural production, which the researches of chemists have proved to be an elementary body. Its sources are extremely numerous. In the simple state it occurs in most volcanic regions, as in Banda and Gunong Karung, in China, in Pegu, and the Philippine Islands. It abounds also in Nipal, Cabul and Armenia; and in the European volcanic districts of Vesuvius and Etna, it is found in equal plenty.

Acidified by oxygen in the state of sulphuric acid, and this acid in combination with soda, lime, baryta, magnesia, oxide of iron, &c. sulphur is also most extensively distributed over this globe. It exists in inconceivable quantities in binary compounds with the metals, especially with iron, lead, antimony, copper, and zinc—nor is it confined to the mineral kingdom, for we find it in many animal and vegetable productions. The serum of the blood of animals and the albumen or white of eggs contain it in a notable proportion. The plants of the family termed *cruciferæ* (or cross-bearing,) from the forms of their flowers, are also rich in this principle; so much so, that the essential oil distilled from the seed of one of these, namely, the common mustard, contains twenty parts of sulphur in one hundred of oil.

From all these sources sulphur is procurable by very simple expedients. Being converted into vapour at the temperature of 600° F. and the vapour being condensible without change, the native or mineral sulphur can be purified from accidental admixture of earth, &c. by mere heating in close vessels—a process called *sublimation*. From the metallic sulphurets, such as those of iron or lead, it is procured by "roasting," the volatile products being condensed in long wooden chimneys.

When perfectly pure, sulphur crystallizes in octohedral forms. At ordinary temperatures, it is a brittle yellow solid of specific gravity 1.99, fusing at 216° F. The effects of heat increased beyond this point are very remarkable. At 280° it is very liquid, and of an amber colour. At 320° it thickens and becomes red, and its tenacity increases to 480°. From that degree to 600° it again liquifies, and above 600° it sublimes. If poured into water when heated to 428° or rather more, it becomes a ductile soft mass, which hardens in some hours, and is used for taking impressions of cameos, seals, coins, &c.

The sublimed sulphur generally occurs in minute crystalline grains, called *flowers* of sulphur. The density of the vapour of sulphur is very great, it being at least six times heavier than atmospheric air. Hence 100 cubic inches should weigh over 200 grains.

Sulphur is insoluble in water, but can combine with it to form a hydrate, the preparation of which is described in the next paragraph. It is soluble in oil of turpentine, and when the vapours of sulphur and alcohol are brought together, a solution is formed.

When boiled in water with lime (oxide of calcium), potash or soda, curious and important changes occur. The water is decomposed, its oxygen forms with one portion of sulphur two oxyacids, the *sulphurous* and *sulphuric.* The hydrogen forms another acid *(sulphuretted hydrogen)* with a second portion of sulphur. These three acids again combine with the lime or other base, forming salts called sulphites, sulphates, and hydro-sulphurets—and any additional sulphur present is dissolved in the solution of the hydro-sulphuret. When this process is performed with lime, (and the experiment can be made in a Florence flask with a few grains of the materials,) by boiling the mixture for a few minutes, the changes above described take place. The *sulphite* of lime rapidly absorbs oxygen from the air and becomes *sulphate* of lime, which, being insoluble, subsides along with the sulphate first formed. A fine golden yellow-coloured liquid remains, which is a solution of sulphur in hydro-sulphuret of lime. If to this we add muriatic acid, a fœtid acid gas, the sulphuretted hydrogen, is expelled, and sulphur is precipitated as a hydrate in combination with one equivalent of water. The lime with the muriatic acid forms a muriate of lime, which remains in solution.

The precipitated hydrate of sulphur thus prepared is quite white, and owing to this property is sometimes substituted for common sulphur in ointments and other medicinal preparations. It is very liable to adulteration with sulphate of lime, the sulphuric acid being substituted for the muriatic in the above process, and an insoluble sulphate of lime thereby mixed with the precipitated sulphur. The fraud is known by heating the suspected specimen to redness. The sulphur is totally dispelled. The sulphate of lime remains.

I have given these minute details, because I have found the process a very useful exercise for pupils. I would take the liberty of recommending district teachers not to pass it over hastily, for the student will derive great assistance from its comprehension in his future chemical pursuits.

The combining proportion of sulphur is 16. With oxygen it forms four compounds:—

Sulphurous acid, ... S, O_2, $= 16 + 16 = 32$
Sulphuric acid, ... S, O_3, $= 16 + 24 = 40$
Hypo-sulphurous acid, S_2, O_2, $= 32 + 16 = 48$
Hypo-sulphuric acid, S_2, O_5, $= 32 + 40 = 72$

SULPHUROUS ACID.

The sulphurous acid is a transparent colourless gas, which is most simply prepared by burning sulphur in oxygen gas. It is also formed when sulphur is burned in the open air. For experimental purposes it is best obtained by heating in a glass retort three parts of strong sulphuric acid with two of the simple metal mercury. A portion of the acid is decomposed by the metal, to which it yields oxygen, and a corresponding quantity of sulphurous acid gas is disengaged. The oxide of mercury with undecomposed sulphuric acid forms a sulphate of the oxide of that metal. This residuum should be preserved for experiments on mercurial preparations.

The gas must be collected over mercury, or by displacement of air, as described under the head of Carbonic Acid. A simple and cheap mercurial pneumatic trough may be made thus:—Cut a cavity three inches deep, twelve long, and six broad, in a solid block of teak or mahogany wood, one inch from the rim, and at one end place a little wooden shelf two inches long, with a hole at its outer edge. With a few stoppered phials, and about 12 lbs. of mercury, nearly every experiment on the gases soluble in water can be satisfactorily performed with this apparatus.*

The sulphurous acid is extremely irritating and irrespirable, its odour very pungent and oppressive. It is a non-supporter

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* A still better apparatus can be made of the same dimensions of double tinned iron lacquered by being rubbed over with melted asphaltum *(ziftiroomee.)*

of combustion, and incombustible itself. Water dissolves thirty-three times its own bulk of the gas, forming an acid solution of remarkable properties. Like chlorine, this acid either in its gaseous or dissolved state, bleaches vegetable and animal colours. Thus a red rose moistened and introduced into a bottle of this gas quickly becomes white; but it is curious that the colour is not destroyed—it may be restored by dipping the flower into a strong acid such as the sulphuric. With alkalies the colour passes to green. Owing to the properties thus described, sulphurous acid is still extensively employed, especially in the bleaching of silks.

Sulphurous acid gas contains its own volume of oxygen, and 100 cubic inches weigh about 68 grains. It has such a power of attraction for oxygen that it separates that element from many of its compounds; for instance, it decomposes the salts of the oxide of gold, and reduces the gold to the metallic state.

The sulphurous acid may, like the *nitrous* acid, be procured in the liquid state, though quite free from water, by condensing the vapour in tubes surrounded by ice and salt. The acid thus prepared boils below the freezing point of water, and while boiling produces such intense cold that mercury may be frozen by its contact.

SULPHURIC ACID.

Sulphuric acid, the *Gandak ká attar* of the Hindus, has been long known among Eastern nations. In Southern India it has been prepared for many centuries, and certainly at an earlier date than its supposed discovery by Bazil Valentine, towards the close of the 15th century. Although the process followed by the Hindus is empirical, it, nevertheless, is practically identical with that grounded on the most scientific principles, and has, moreover, the advantage of being simple, economical, and suited to their existing wants.

It would be impossible to exaggerate the importance of this acid, whether we consider it with reference to abstract science, to the condition of our manufactures, or the purposes of medicine. By the assistance of this acid we prepare almost all the others: for instance, the nitric, muriatic, tartaric, citric, &c. We owe to it the cheapest mode of obtaining artificial soda, chlorine, and its bleaching compounds. It is essential to the processes of the dyer, and to it we are indebted for many of the best remedies we can command—of which calomel, corrosive sublimate, sulphate of quinine, the ethers, &c. may be cited as examples. In fact, from the time that sulphuric acid was first prepared at a cheap price in Europe, may be dated the commencement of her greatness in all chemical manufactures. These instances of the utility of this acid should lead us to study its preparation and properties with care; the more so, since in the vast territories of British India there are but two manufactories of sulphuric acid at present in existence.

The process for the preparation of sulphuric acid on the large scale will be intelligible from the following data :—

Sulphurous acid gas contains 100 measures oxygen, 100 vapour of sulphur, in 100 volumes. Sulphuric acid vapour contains the same volume of sulphur, with 150 of oxygen.

Now if we introduce 100 measures of sulphurous acid and 50 oxygen into a glass jar over mercury, we have the exact *proportions* for forming the sulphuric acid. But in this state chemical union does not take place; the two gases remain merely mixed with each other.

If we now introduce some nitric oxide, (see page 41) prepared over *water*, the nitric oxide at once unites with the oxygen, and becomes *nitrous* acid vapour. This vapour is immediately decomposed by the sulphurous acid gas, which attracts oxygen from the nitrous acid, converts it into hypo-nitrous acid, and itself becomes sulphuric acid, (see page 44—article " Nitrous Acid.")

The sulphuric and hypo-nitrous acid thus formed, with the watery vapour contained originally in the nitric oxide, (from its having been collected over water,) combine together and concrete on the interior of the glass jar in beautiful leaf-like crystals. By introducing a few drops of water the crystals are decomposed with effervescence, sulphuric acid being dissolved, and the hypo-nitrous acid converted into nitric oxide and nitrous acid.

By admitting fresh oxygen these changes may be repeatedly witnessed until all the sulphurous acid first employed is oxydized to the maximum, and converted into sulphuric acid.

Thus gaseous sulphurous acid and oxygen do not combine directly. They require the intermediate agency of the nitric oxide—and a small quantity of this gas will successively take up and transfer large portions of oxygen to the sulphurous acid, the nitric oxide itself ultimately undergoing but little diminution.*

Such is precisely the series of decompositions which take place on the gigantic scale on which the manufacture of sulphuric acid is now conducted. Eight parts of sulphur and one of nitrate of potash are burned in contact with atmospheric air in a furnace, which leads the gaseous products of the combustion into capacious chambers built of lead. A small portion of the sulphur first attracts oxygen from the nitre, becomes sulphuric acid, which at once unites with potash forming sulphate of potash. The rest of the sulphur with oxygen of the *air*, becomes sulphurous acid gas, which enters the chamber in great volumes. *Nitric oxide* is at the same moment disengaged from the decomposed nitre: it attracts oxygen from the *air*, and forms nitrous acid vapour. The floor of the chamber being covered with water, we have consequently present all the substances essential for the changes I have above described. The crystals of sulphuric

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* It has recently been discovered that by forcing a mixture of these gases in the requisite proportions through a tube containing spongy platinum and heated to redness, they unite and form sulphuric acid.—It is not improbable that this process may be successfully applied to the preparation of the acid *on the small scale* for the purposes of the pharmaceutical chemist.

and hypo-nitrous acid are formed and decomposed, and the series of phenomena carried on again by the aid of the nitric oxide gas.

The dimensions of such a chamber vary in different establishments. The usual proportions are 15 feet high, 27 broad, 50 long, giving a capacity of 20,250 cubic feet. The average produce of strong acid is 250 lbs. to every 100 lbs. of sulphur employed. The acid drawn off from the floor is generally of the density of 1,200, and in this state contains a large quantity of water and sulphurous acid, from which it must be freed before it can meet a market. The density of the standard acid is 1,850, and its boiling point 6 20°—beyond the temperature at which lead melts.

To concentrate the acid, the liquid first drawn from the chamber is boiled in leaden pans, until the greater portion of its water is expelled. It is then removed to glass or platinum retorts, and boiled down to the greatest density. When glass vessels are used, to avoid the concussions of the heavy boiling acid, pieces of glass or platinum are introduced, which are found to prevent the violent ebullition. The expense of a good platinum retort and head capable of boiling down 150 seers is about 7,000 rupees. The operation may be performed seven times in 24 hours—so that estimating the interest of capital at six per cent. the expense of concentrating 100 seers of acid would amount to about two rupees. When glass vessels are employed, the average breakage is one of every five retorts; so that the platinum, though originally most expensive, is at length the most economical of all.*

The old method of manufacture was by burning the mixture of sulphur and nitre in large glass bells. Earthen vessels of similar form are still used in Southern India, and with advantage.

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* A platinum retort of very large size has been used night and day for eighteen years, and at the end of that period, it had not lost weight in a balance which turned to two grains in either scale.

Several improvements have been suggested within the last few years in various steps of this manufacture. To avoid the loss of sulphur in the generation of sulphate of potassa, it was proposed to burn the sulphur, and fuse the nitre in separate vessels, but the attempt proved a complete failure. The French burn the sulphur separately, but extricate the nitric oxide from a mixture of nitric acid and coarse sugar—a plan which seems to have succeeded very well. Instead of a layer of water on the floor of the leaden chamber, the gases have been condensed by a jet of steam; but this method is found to endanger the whole structure, the total and rapid condensation which occurs causing the walls to be burst in by the pressure of the atmosphere. To do away with the expence of leaden chambers, buildings of stone coated with resinous cements have been unavailingly tried.*

One rather successful experiment was made, however, by Mr. Porteous of this city, who tried, with great advantage, a mixture of sea-sand and shell-lac as a coating to an old leaden chamber. As lac is insoluble in the *dilute* acid, I have little doubt but that chambers of masonry—or even of solid wood-work lined with sand and lac, might be constructed to any extent, if the cooling of the vapours could be accomplished. Sheet iron lacquered with asphaltum completely resists the vapours, and might be tried instead of lead with much likelihood of success.

I have stated that the return of concentrated acid was generally 250 per cent. of the sulphur employed. This is 56 less than the theoretical product should, and doubtless might, be; for 100 sulphur combine with 150 oxygen and 56 water to form acid at 1.850. The causes of loss are chiefly twofold; first, the conversion of sulphur into sulphate of potash; and, secondly, the actual sublimation of sulphur into the chamber where it is deposited and mixed with the acid. This

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* Chiefly because being bad conductors of heat, the vapours were not condensed. The cooling power of the extensive metallic surface of the leaden chamber exposed to the air, contributes much to the success of this manufacture.

is destructive not only from the first loss, but if the acid containing sulphur be concentrated, the free sulphur decomposes sulphuric acid, both being converted into the sulphurous acid. 100 parts of sulphur will thus decompose 612 of acid, and as the 100 sulphur should itself produce 300 acid, the total loss on the deposition of 100 lbs. sulphur would amount to beyond 900 lbs. of concentrated acid. When the deposit occurs, the acid must be filtered through sand before concentration.

Besides these sources of loss, the nitrous acid is sometimes changed into the nitric by the air and water in the chamber. This only occurs, however, at the commencement of each operation; for when the water on the floor is impregnated with the sulphuric acid, it does not occasion the change in question. The nitric acid is extremely prejudicial in several points of view. Thus it renders the sulphuric acid nearly useless to the blue dyer, because it destroys indigo colours, for the solution and application of which the sulphuric acid is the agent chiefly employed.

Besides the nitric and sulphurous acid, the sulphuric acid of commerce frequently contains sulphate of potassa and of lead, proceeding from the potash of the nitre and the lead of the chamber and evaporating vessels. These substances are of little consequence in large operations. To free the acid from them for nice chemical experiments, it must be distilled from glass or platinum vessels.

To give some idea of the enormous quantity of this acid consumed in Europe and America, I need only cite the return given by Dumas of the manufacture of the article in *one* district in France in the year 1826. There were eight factories, the produce six millions of pounds, the expense of production 28,000*l.*; the acid was sold at three pice per lb. and produced 34,400*l.*, the sulphur paying a duty of 20, and the saltpetre of 50 per cent. Since the first edition of this work was published, the consumption of the acid has nearly trebled in England, and its price fallen to one penny the pound.

The properties of the concentrated acid are very remarkable. It is a dense, colourless, oily-looking fluid, from which appearance it was called the "oil of vitriol" by the early writers. It is extremely corrosive, charring and destroying all vegetable and animal structures. This it effects by causing their hydrogen and oxygen to combine so as to form water, and setting their carbon free—thus causing a black stain wherever it touches. It is the strongest acid we know, decomposing the salts of all other acids. The affinity of sulphuric acid for water is very great. When four parts of acid are suddenly mixed with one of water, the temperature rises to 300° Farht.

The strength of the acid may be ascertained by the quantity of dried carbonate of soda it will neutralize. Every 40 parts of acid require 53 of soda, the neutral salt, sulphate of soda, being formed.

With the oxide of barium, baryta, a common and well known earth, sulphuric acid forms an extremely insoluble compound. Solutions of barytic salts are hence used as tests for sulphuric acid. If nitrate of baryta be added to a liquid containing sulphuric acid, a sulphate of baryta is thrown down which is completely insoluble in nitric acid, and of which 116 parts by weight contain 40 of the real acid.

Besides the acid thus described there are two other varieties of sulphuric acid which demand a cursory notice. The first is—

THE SOLID SULPHURIC ACID.

This may be regarded as the very purest sulphuric acid. The ordinary acid contains at least one equivalent of water; this is anhydrous altogether. It may be prepared by exposing the sulphate of protoxide of antimony to heat, or by boiling the acid described in the next paragraph, and in each case condensing the vapours in a cold receiver. The solid sulphuric acid occurs in white elastic crystals. It attracts water so eagerly, that when dropped into that fluid it hisses like red hot iron. It is a rare and curious substance, but only interesting for theoretical considerations.

The last variety is—

THE FUMING, OR NORDHAUSEN ACID.

This is a compound of the common acid, the solid acid, and of variable proportions of sulphurous acid gas. On boiling, the two latter substances are expelled, and the common acid remains.

This acid derives its name from that of the town where it is chiefly manufactured. Its principal employment is as a solvent for indigo for the use of the dyer, and I believe the process may, for many reasons, be advantageously resorted to in this country.

The acid in question is prepared from a very cheap abundant salt, the protosulphate of iron, or *kasis* of the bazars. In the crystalline state this salt contains six equivalents of water, five of which are expelled by a gentle heat. On urging the heat, sulphurous acid gas first appears; then sulphurous acid and oxygen come over; lastly, solid sulphuric acid is disengaged, and the red peroxide of iron remains in the vessel in which the salt was heated.

The operation may be conducted in earthen or iron tubes heated to redness in a furnace. The density of the acid obtained is rather greater than that of the common sulphuric acid. The reader is referred to the section on "Iron" for further information on the circumstances to be attended to in the preparation of the sulphate of iron, so as to render this mode of making acid available in particular localities in this country.

The Hypo-sulphurous acid. This acid is of very little importance, and prepared with great difficulty. A hypo-sulphite of lime may be prepared by boiling three parts of lime and one of sulphur, in 20 of water for an hour, and decanting the clear liquid, and passing through it a current of sulphurous acid gas. When neutralized, the solution, which is intensely bitter, possesses the property of dissolving chloride of silver, a tasteless compound, and forming with it a liquid of peculiarly sweet taste.

The Hypo-sulphuric acid is prepared by transmitting a current of sulphurous acid gas through water containing peroxide of manganese in fine powder, and kept cold by a mixture of ice and salt. Filter the liquid, add a solution of pure baryta, (see that head,) and a solution of hypo-sulphate of baryta is obtained, from which the baryta may be separated by sulphuric acid. The experiment is difficult to the unpractised, and leads to no instructive result.

COMPOUNDS OF SULPHUR AND HYDROGEN.

These are two in number, and are thus composed—

	Sulphur.	*Hydrogen.*
Sulphuretted hydrogen,......	1 eq. = 16	1 eq. = 1.
Persulphuret of hydrogen, .	2 eq. = 32	1 eq. = 1.

The first of these compounds is also termed the hydro-sulphuric acid. It is a gaseous acid substance of great importance.

It is prepared by heating the sulphuret of antimony (*súrmeh*) with strong muriatic acid in a glass flask, a sesqui-chloride of antimony is formed, and sulphuretted hydrogen disengaged in the gaseous state. The proto-sulphuret of iron when acted on by four parts water and one sulphuric acid also affords sulphuretted hydrogen, the water being decomposed, and a sulphate of the oxide of iron formed. The proto-sulphuret of iron is prepared by heating together four parts of iron filings, and less than two parts of sulphur by weight. The materials should be mixed in a thin glass flask, and placed on a small charcoal fire. Long before the glass is heated even to redness, the mixture of sulphur and iron unites with a vivid glow of light and intense heat. The flask should be then removed and allowed to cool. It should then be broken, and the sulphuret of iron preserved for use in a stoppered bottle.

To prepare the sulphuretted hydrogen gas from the materials thus described, a small retort, or bottle with a bent tube, should be used, and the gas collected over warm water.

Sulphuretted hydrogen is colourless, highly soluble in water, of an insupportably offensive smell, resembling putrifying eggs, altogether irrespirable, and one of the most poisonous of all gases, one part in 1,000 of common air having been known to kill a dog. It is even poisonous when applied to the skin alone, as the experiments of Chaussier have fully established. It burns with a pale blue flame, depositing sulphur, and producing sulphurous acid and water. It does not support combustion itself. 100 cubic inches weigh 36½ grains. It contains its own volume of hydrogen gas, and consequently requires 150 measures of oxygen to convert it into water and sulphurous acid. It is at once decomposed by chlorine, which takes its hydrogen and sets the sulphur free—thus, on mixing chlorine and this gas over warm water in a glass jar, the sides of the vessel are coated with a yellow layer of pure sulphur.

If a drachm or two of fuming nitric acid be poured quickly into a jar of this gas it is at once decomposed, its hydrogen forming water with the oxygen of the acid. A blue flame shoots through the mixture at the moment of the decomposition.

Sulphuretted hydrogen affords an invaluable agent to the analytic chemist. If brought in contact with neutral solutions of the oxides of several metals, water and an insoluble sulphuret of the metal are formed by double decomposition. The colours of these sulphurets vary in many cases. That of arsenic is yellow, of antimony orange red, of silver, iron, bismuth, lead, &c. black; of zinc, white, &c.

Under the section of the detection of poisons, numerous useful applications of these facts will be explained.

Sulphuretted hydrogen is termed an acid gas because it reddens vegetable blue colours, such as paper tinged by litmus, and it unites also with the alkalies potash, soda, and ammonia to form salts. These salts when acted on by acids of almost any other kind are decomposed, and the sulphuretted hydrogen evolved. It exists, too, in many mineral springs, in which it may be at once recognised by its offensive odour, and by its immediately giving a black stain to any of the compounds of silver or lead.

The *Persulphuret of hydrogen* is a yellow, oily, and fœtid liquid, prepared by a very complicated process, and devoid of the least interest in a practical point of view.

SECTION IX.

IODINE, ITS COMPOUNDS WITH HYDROGEN, OXYGEN, AND NITROGEN.

This important element was discovered accidentally by M. Courtois in 1812. It has not hitherto been found uncombined in the native state, but associated with sodium and potassium it exists in great abundance. United with sodium it occurs in many mineral springs, in the waters of the Mediterranean and of the Bay of Bengal, in almost all kinds of sea-weed,* and in many marine animals. In the mineral kingdom also it has been found in combination with silver.

Iodine is prepared on a large scale from an impure kind of carbonate of soda called kelp, made in many parts of Europe by burning sea-weed. The soda is used by the soap-makers, and the part of the kelp which they reject, contains iodine combined with sodium. If to this liquid some peroxide of

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* I have detected it since the publication of the first edition in the *conferva*, or green slimy weed, which accumulates on the surface of the Salt-water lake, near Calcutta.

manganese and sulphuric acid be added, and heat applied, the oxygen gas unites with the sodium, and iodine is disengaged in beautiful purple vapours. The decomposition is precisely similar to that which takes place in the preparation of chlorine. The purple vapours condense on any cool surface, in branching crystals of a deep iron-grey tint and metallic lustre. These crystals are soft, opaque, easily reduced to powder. They fuse at 225°, and sublime unaltered. Their density is found to be more than three times greater than that of the same bulk of water.

Iodine is acrid to the taste: its odour resembles that of chlorine. It is but little soluble in water, but dissolves copiously in alcohol and ether, giving a deep reddish solution. With starch it forms a beautiful blue compound, which is readily prepared by adding a few drops of the alcoholic solution of iodine to water in which a little flour has been boiled. The flour contains starch which is dissolved by the boiling, and this solution must be allowed to cool before the iodine is added. A splendid blue colour is instantaneously produced. If a little of the blue solution be heated in a glass flask, its colour is discharged the moment the liquid reaches the boiling point. If the bleached liquid be suddenly cooled by plunging the flask into cold water, the blue colour is quickly restored—and this curious experiment may be repeated many times with the same portion of fluid. The effect, moreover, is produced with such extreme delicacy, that a liquid containing but $\frac{1}{450,000}$th of its weight of iodine, receives a blue tint when a solution of starch is added.

It is to be observed, too, that it is only the *free* iodine which produces these effects: none of its compounds are altered in colour until their iodine is disengaged.

The equivalent or combining number of iodine is proved to be 126. Its vapour is remarkably dense, 100 cubic inches weighing nearly 270 grains, more than eight times the weight of the same bulk of atmospheric air.

HYDRIODIC ACID.

When sulphuretted hydrogen gas is passed through water mixed with the blue compound of iodine and starch, the colour rapidly disappears; the hydrogen and iodine form hydriodic acid, which is dissolved by the water, and sulphur and starch are precipitated, and may be removed by filtration.

But in its uncombined state the hydriodic acid is a gaseous substance. In this form it may be prepared most conveniently by the following process. Mix one part of *phosphorus* cut very small (see that head), with ten of iodine moistened with water, and previously introduced into a small glass retort. Decomposition of the water forthwith takes place, with a slight explosion. The oxygen forms phosphorous acid, and the hydrogen unites with the iodine, and is disengaged in the gaseous state. As it is very soluble in water, and is decomposed by mercury, it is best collected by displacement in the mode described in the sections on the carbonic and muriatic acids. Five grains of phosphorus and fifty of iodine will be sufficient for the experiment.

If a jar of this gas be placed over mercury, the iodine combines with the metal, and half the jar full of hydrogen gas is left. If a little chlorine be disengaged from a tube or small retort over a jar of hydriodic acid, rich purple vapours of iodine immediately appear and concrete on the sides of the vessel, the hydrogen and chlorine forming muriatic acid. Or if fuming nitric acid be poured into a vessel containing this gas, the oxygen of the acid removes the hydrogen, and the iodine is deposited in the same manner. The mixture in this experiment often inflames, even when very minute quantities of the materials are employed.

These and similar experiments shew that hydriodic acid gas is composed of equal volumes of iodine vapour and hydrogen united without condensation. One hundred cubic inches must hence weigh 136 grains. Its density is consequently more than four times that of atmospheric air.

The solution of hydriodic acid gas in water when concentrated possesses strong acid properties. It decomposes carbonates, reddens vegetable blues, and unites with the alkalies to form salts called *hydriodates:* of these the most important is the hydriodate of potash. In strict chemical language, this salt in the *dry state* is an iodide of potassium, the hydrogen of the acid and oxygen of the base being expelled as water by the drying of the salt. When dissolved in water, however, the solution may be regarded as that of a hydriodate of potash. If in this state it be added to the solutions of several metallic oxides, such as those of lead or mercury, the oxide and the hydriodic acid undergo mutual decomposition—an insoluble ioduret of the metal and water being formed. Thus with a solution of nitrate of silver there is a yellow, with pernitrate of mercury a red, with acetate of lead a yellow precipitate. If starch be mixed with a solution of hydriodate of potash, no change of colour ensues, but if nitric or sulphuric acid be added, the hydriodic acid is separated and decomposed, its iodine being set free, and then the characteristic blue colour at once appears. A solution of chlorine in water produces the same effect.

An *oxide of iodine* and an *iodous acid* have been described, but their properties have not been exactly ascertained.

Iodic Acid. When iodine, water, and potash or soda are boiled together, by the decomposition of water hydriodic and iodic acids are formed, both of which unite with the alkali employed. The hydriodate is soluble in alcohol, by which the iodate is not dissolved. If this iodate be boiled in concentrated sulphuric acid, sulphate of soda is formed, and iodic acid crystallizes in six-sided plates. Or if iodine be boiled for several hours in nitric acid in a very deep glass vessel, this acid is produced.

It is a white semi-transparent solid of sour taste, but devoid of smell. As it contains five atoms of oxygen to one of iodine, it yields oxygen readily to all combustible bodies, thus giving rise to several explosive compounds. Whenever it is deprived of oxygen, a corresponding proportion of iodine is set free. Thus if we pass a current of sulphuretted hydrogen through a solution of iodic acid, sulphuric acid and water are formed, and iodine is disengaged.

There is another compound of iodine and oxygen, the *periodic acid*, which has been lately discovered, but its properties are not of sufficient importance to require more particular notice. The same may be said of the chlorides of iodine, and its compounds with sulphur and carbon.

THE TER-IODIDE OF NITROGEN.

This is a curious, though not a useful substance, is easily prepared, and a source of much amusement to the experimentalist.

It is best made by mixing a strong alcoholic solution of iodine with liquid ammonia, (see that section). On adding water a black powder subsides, and may be separated by filtration. When the powder is dry, the slightest touch or increase of temperature causes it to explode with a sharp report.

In this process a portion of the ammonia (nitrogen one eq., hydrogen three eq.,) suffers decomposition. Three atoms of iodine with one of nitrogen form the explosive compound. The hydrogen of the ammonia with iodine forms hydriodic acid. A hydriodate of ammonia thus remains in solution.

Iodine and several of its compounds are remarkable for their medicinal virtues, especially in the cure of goitre, scrofula, and syphilis. The medical student should consequently bestow much attention on this subject.

SECTION X.

PHOSPHORUS AND ITS COMPOUNDS WITH OXYGEN AND HYDROGEN.

This elementary substance was discovered by Brandt, of Hamburgh, in 1669. It derives its name from its property of emitting light in the dark.

Phosphorus is not found in nature in the uncombined state, but associated with oxygen and hydrogen it occurs in great abundance. Among its oxy-acids the phosphoric united with lime is the most plentiful; the phosphate of lime constituting the basis of the bones in all the higher animals. Mineral phosphates of the oxides of metals are also found in considerable quantities.

Bones afford the best material for the preparation of this element. They are burned in the first place in order to destroy all the animal matter they contain. A white substance remains, composed chiefly of phosphate and carbonate of lime. To this made into a paste with water, half its weight of sulphuric acid is added, and the mixture is allowed to stand for two or three days. The sulphuric acid decomposes part of the phosphate of lime, sulphate of lime and phosphoric acid being formed. This phosphoric acid then unites with undecomposed phosphate of lime, forming a bi-phosphate of that base. The double phosphate is very soluble, the sulphate of lime insoluble in water; we can therefore separate these compounds from each other by washing and filtration.

The solution of bi-phosphate of lime is then evaporated to dryness, mixed with a fourth of its weight of powdered charcoal, and heated to redness in an earthen retort. The charcoal takes oxygen from the phosphoric acid, and a corresponding portion of phosphorus is disengaged in the state of vapour, and condensed in cold water.

This process is very difficult, and seldom succeeds but on a very large scale. The product nevertheless is cheap, being sold in Europe for about three shillings the ounce.

Phosphorus is a transparent, almost colourless solid, of waxy consistence, and smell resembling garlic. It is soluble in oils and naptha, from which it can be made to crystallize. It fuses under water at 108°, and if heated to 150° and suddenly poured into very cold water it becomes black, but regains its natural appearance by slow fusion and cooling again.

The most remarkable property of phosphorus is its excessive inflammability. At natural temperatures it combines with oxygen, undergoing slow combustion, and emitting a faint light and low degree of heat. It is inflamed by a slight degree of heat above its melting point, by pressure, friction, or the electric spark. Introduced into a vessel of pure oxygen gas below the temperature of 80°, no union occurs; but if nitrogen, hydrogen, or carbonic acid be present, the oxidation occurs as low as 60°. It may be heated even to its subliming point in common air, without attracting oxygen or inflaming, provided the vapour of oil of turpentine be present.

There is some doubt as to the combining proportion of phosphorus. Dr. Turner adopts 15 and a fraction. But double that number 31. 4 is now generally admitted to be more correct. Its oxides are four—there being three modifications of the last, which cause it to receive different names, though no difference of composition exists. These compounds may be represented as follows :—

		Phosp.		*Oxygen.*	*Equiv.*
Oxide of phosphorus	2 eq. =	62,8	1 eq.	8 =	70,8
Hypo-phosphorus acid	1 eq. =	31,4	1 eq.	8 =	39,4
Phosphorus acid	1 eq. =	31,4	3 eq.	24 =	55,4
Phosphoric acid, ... Pyro-phosphoric acid, ... Meta-phosphoric acid, ...	1 eq. =	31,4	5 eq.	40 =	71,4

The *oxide* of phosphorus is a red substance of no particular interest. The *hypo-phosphorus acid* is made by rather an intricate process, and demands no more than the preceding notice of its composition.

PHOSPHORUS ACID.

This compound is slowly generated when phosphorus is exposed to the open air, being deposited as a white powder. When bichloride of mercury (corrosive sublimate) and phosphorus are distilled together, a chloride of phosphorus is produced, which is decomposed by water, hydro-chloric acid and phosphorus acid being formed. The former is expelled by evaporation, the latter crystallizes in combination with one equivalent of water.

During the combustion of phosphorus in a vessel of air, a portion of phosphorus acid in the anhydrous state is produced.

The chief peculiarity of the phosphorus acid is its strong attraction for oxygen. It is thereby enabled to decompose the salts of the oxides of platinum, silver, and gold, reducing the metals to their simple state.

PHOSPHORIC ACID.

When phosphorus in small pieces is heated with strong nitric acid, violent action ensues; nitric oxide is disengaged and phosphoric acid formed. The experiment should be conducted in platinum vessels, for the phosphoric acid rapidly corrodes glass.

Or the biphosphate of lime, previously described, may be neutralized with ammonia. Phosphate of lime is precipitated, phosphate of ammonia remains in solution. On evaporating this to dryness and igniting the residue, the ammonia is expelled. Finally; the phosphoric acid is obtained by dissolving the ignited solid in water.

This acid is colourless, and very sour to the taste. It consists of 1 eq. of phosphoric acid, and 3 eq. of water. It is remarkable for its tendency to unite with three equivalents of any base, or with one or two equivalents of a base with the corresponding number of equivalents of water. When neutralized with ammonia it causes a yellow precipitate in neutral solutions of silver.

If heated to 415° it undergoes changes in its properties, though not in its ultimate constitution. After this process, if neutralized with ammonia it precipitates the salts of silver *white;* it unites with but two equivalents of a base, or one of water and one of oxide. The acid thus modified is called the *pyro-phosphoric* acid, from πυρ, fire, because the readiest mode obtaining it is by the action of heat on the true phosphoric acid.

The *meta-phosphoric* acid is formed when phosphorus is burned in dry air or in oxygen gas, or when the phosphoric or pyro-phosphoric acids are heated to redness. This acid unites with but one equivalent of a base, and it gives grey precipitates with the silver salts.

The strictest analysis has shewn that these three acids, however different in properties, are still identical in composition. Numerous instances of this occurrence will meet us as we proceed. Bodies thus constituted are termed *isomeric,* a word of Greek origin, signifying "equal proportions."* Under the heads of tartaric, cyanic, and meconic acids, the carburets of hydrogen, &c., examples of such compounds will be found.

PHOSPHURETTED HYDROGEN.

There are two isomeric gases, both containing 50 volumes of phosphorus vapour, and 150 hydrogen condensed into 100 measures. One of the gases inflames spontaneously when it comes in contact with the air; the other does not possess

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* Professor Graham is of opinion that this does not constitute an example of isomerism, but that the difference consists solely in the different proportions of *water,* with which the acid is combined in these three modifications. Viewing the water as a base, he terms these varieties of phosphoric acid, the *monobasic, bibasic,* and *tribasic* phosphates of water.

this property, and moreover unites with hydriodic acid to form a salt which occurs in cubic crystals.

If 40 grains of phosphorus, 50 of caustic potash, and 60 drops of water be mixed in a very small retort, and gently heated, abundance of this gas is disengaged. The neck of the retort should dip in a very shallow cup of water. The water in this process is decomposed, phosphuretted hydrogen being disengaged, and phosphorus and phosphoric acid remaining in solution in the retort.

Every bubble of this gas as it rises through the water inflames with a vivid flash, and a wreath-like circular band of smoke is formed, which gradually enlarges as it ascends, presenting an indescribably beautiful appearance. If the beak of the retort be held beneath a jar of oxygen gas, every ascending globule causes a dazzling flash and explosion. In this experiment, however, the apparatus is often broken, and accidents are not unfrequently occasioned.

The phosphuretted hydrogen is absorbed copiously by a solution of sulphate of copper, and its degree of purity may be thus conveniently tested. The odour of the gas is extremely disagreeable. Its spontaneous inflammability is soon destroyed by the presence of minute quantities of charcoal or potassium, the vapours of essential oils, ether, olefiant gas, &c. and in none of these cases is the gas altered in volume. On the other hand, the variety of phosphuretted hydrogen which does not inflame spontaneously, acquires the power if mixed with one part of nitrous acid to one thousand measures of the gas.

Phosphuretted hydrogen is a frequent natural production. Its flame is often seen hovering over burial grounds or marshes where decaying animal matter disengages its elements in the gaseous state. There is an extraordinary fountain near Chittagong, which constantly discharges large volumes of this gas; and in the *Journal of the Asiatic Society*, two instances are narrated of the extrication of phosphuretted hydrogen from cess-pools in Calcutta.

SECTION XI.

BORON AND BORACIC ACID.

United with oxygen and soda, this element exists abundantly in the well-known salt, borax or tincal, the *sohágá* سوھاگا of the Hindus, the produce of Persia, China, and Thibet. With oxygen alone it occurs as boracic acid, in several hot springs in Italy.

Borax is a compound of 2 eq. boracic acid, 1 eq. soda, and 10 eq. of water. If dissolved in boiling water, and sulphuric acid be gradually added, sulphate of soda is formed, and the boracic acid is deposited in scaly crystals as the solution cools. This should be washed with cold water, and fused in a platinum crucible to render it perfectly pure. It is soluble in alcohol, and the solution burns with a beautiful green flame. It has the singular property of acting on turmeric paper like an alkali, namely, changing it to a brown colour. It is very fusible, and increases the fusibility of various minerals, with which it forms glasses of different and characteristic colours. In the section on the use of the blow-pipe, many useful applications of this property will present themselves.

Boracic acid is decomposed by the Galvanic Battery, its oxygen evolved, and the element Boron obtained in the simple state. Or it may be procured by heating the acid with potassium. Boron is a dark olive-coloured body, about twice the density of water, destitute of any very remarkable properties, and easily changed into boracic acid by burning in the open air, or boiling in nitric acid. Its combining number is estimated at 10 and a fraction, and the boracic acid contains 3 equivalents of oxygen.

SECTION XII.

SELENIUM AND ITS OXIDES.

Selenium has hitherto been procured but in extremely minute quantities, and though its properties have been exactly studied, it does not seem susceptible of any useful application. It occurs in nature, in combination with sulphur, iron, lead, and other metals. These compounds are mixed with peroxide of manganese, and heated in a retort. Sulphurous acid is formed and selenium volatilized, sometimes in combination with oxygen—but when the oxide meets the solution of sulphurous acid in the water of the receiver, it yields it its oxygen and selenium is deposited.

Selenium is a brittle, opaque, tasteless, inodorous substance, resembling lead, but its powder is of a red colour. It is four times as dense as water, becomes soft and tenacious at 212°, when it can be drawn out into transparent threads. It melts at 240°, boils at 650°, and evolves a yellow vapour. It is insoluble in water, and when heated in the open air, unites with oxygen in two proportions, forming the selenious and selenic acids. During this change it evolves so powerful an odour of horse-radish, or of its Indian substitute the *moringa* or *sahajná*, that the smallest particle can be smelt over a large apartment.

The *selenious acid* is a white crystalline solid. The *selenic acid* is a colourless liquid, which resembles the sulphurous acid in several of its properties. The salts these acids form also shew a decided similarity in shape, colour, and general properties.

SECTION XIII.

BROMINE AND ITS COMPOUNDS.

Bromine, so called from its heavy, unpleasant smell, βρωμος, resembles chlorine and iodine in many of its qualities, and in the sources whence it is derived.

It exists in minute quantities in combination with hydrogen, soda, and magnesia, in sea water, in some mineral springs, in a few marine plants and shell-fish. When sea water is evaporated for the separation of its salt, the residual liquid called *bittern* retains the compound of bromine and hydrogen in solution. A current of chlorine gas decomposes the hydro-bromic acid. Bromine is liberated, and may be expelled by a gentle heat in heavy red vapours, which condense in the receiver into a liquid of a deep red colour. Liquid bromine is of specific gravity 3; extremely volatile, very soluble in ether, possessing bleaching powers like chlorine; very corrosive and extremely poisonous; one drop being sufficient to deprive a small animal of life. Its combining number is about 78°.

With hydrogen it forms the hydro-bromic—with oxygen the bromic acids, both of which are strongly analogous, in composition and properties, to the muriatic and hydriodic, the chloric and iodic acids respectively.*

With iodine, sulphur, phosphorus, chlorine, and carbon, this element forms binary compounds of little importance.

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* The Bromide of Sodium has been lately recommended by Dr. Williams, as a remedy in enlarged spleen.

SECTION XIV.

FLUORINE AND ITS COMPOUNDS WITH HYDROGEN, BORON AND SILICIUM.

The existence of an elementary substance named Fluorine, has been admitted by all chemists for many years on evidence I shall immediately explain, but it was not obtained in the uncombined state until 1833, when Mr. Faraday separated it during his researches on electricity.* He has not yet published a detailed account of his observations. In the Philosophical Magazine for August, 1836, there is a paper by Mr. Knox, describing several experiments, which are quite conclusive that fluorine, in small quantities, was obtained by the process he describes.

The chief source of fluorine is a mineral called fluor-spar, which occurs in great quantities in many countries, especially in Derbyshire, and which is composed of fluorine and calcium, the metallic basis of lime.

When this fluoride of calcium is acted on by strong sulphuric acid, a portion of the water of this acid is decomposed: its hydrogen with fluorine forms hydro-fluoric acid, which is disengaged in the state of vapour. Its oxygen with the calcium generates lime; and this, lastly, with sulphuric acid forms the sulphate of lime.

From the researches of Mr. Knox, fluorine seems to exist as a gas of a yellowish colour. It attacks and corrodes all metallic and organic substances with such power, that no vessels could be obtained to conduct the necessary experiments, until Mr. Knox ingeniously used the fluor-spar itself in the construction of his appartus.

The hydro-fluoric acid is a colourless volatile liquid, the most corrosive of any with which we are acquainted. The minutest drop instantaneously destroys the skin, producing

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* See the Philosophical Transactions for that year.

an intractable and very painful ulcer. It corrodes glass, the fluorine uniting with its silicium to form a gaseous fluid. Hence the process for obtaining hydro-fluoric acid can only be carried on safely in leaden, silver, or platinum vessels.

Glass is essentially a compound of flint (oxide of silicium) and potash or soda. The hydrogen of the acid and oxygen of the flint form water, and the fluorine and silicium constitute the *fluo-silicic acid* gas. Powdered glass or flints mixed with fluor-spar and sulphuric acid, yield the gas in large quantities. If the beak of the retort (a glass one may be used) be dipped under water, every bubble of the gas is decomposed by that fluid; silica being deposited in the solid state like layers of membrane, and hydro-fluoric acid being retained in solution. The gas may be collected in the pure state over mercury. It is colourless and transparent, extremely irritating; does not support combustion, and its density is more than thrice that of atmospheric air.

Owing to the reaction above described, the hydro-fluoric acid may be conveniently used for etching on glass. The glass to be acted on is first covered with a thin coat of wax; the design is then traced with a needle, leaving the glass bare at every line. If hydro-fluoric acid be poured on the surface thus prepared, or if fluor-spar in fine powder be sprinkled over it, and then strong sulphuric acid poured on, the glass is corroded uniformly wherever the hydro-fluoric acid touches it, and on melting off the wax the design remains.

A gaseous compound of *fluorine* and *boron* is obtained by heating together strong hydro-fluoric and boracic acids. It is a colourless irritating acid gas, incombustible, and destructive to life and flame. It is rapidly absorbed by water, with which it forms an acid solution. So powerfully does this gas attract water, that when it comes in contact with the air, it separates and combines with its watery vapour, forming dense white clouds. It does not attack glass, and can be collected over mercury. When heated with potassium, the latter unites with both the boron and fluorine, and by washing the compound with water the fluoride of potassium is removed and the element boron remains.

The preceding facts have been recently applied with great success to the examination of soils and minerals containing silica. The mineral is mixed with hot water, and subjected to the action of hydro-floric acid vapour. The silica is thus removed in the gaseous state, and the loss of weight shews the amount originally present.

SECTION XV.

ON AMMONIA (TER-HYDROGURET OF NITROGEN) AND ITS COMPOUNDS WITH THE SUBSTANCES PREVIOUSLY DESCRIBED.

There is a well known salt sold in every bazar in India, termed *naushádar* (نوشادر). In English it is called familiarly *sal-ammoniac;* its scientific name is Muriate of Ammonia, significant of its origin.

This salt occurs in commerce in large, firm, rather elastic crystalline cakes. It is soluble in its own weight of boiling water, two-thirds of the salt being deposited in fine feathery crystals as the solution cools. If dissolved in cold water, the temperature of the solution falls 32 degrees. It is also soluble in alcohol. It does not fuse when heated, but at rather a low temperature it sublimes unchanged.

This salt is found as a natural production in volcanic countries, especially in Persia and Armenia. In the province of Mekran in Persia, there is a mountain called Koh Nowshadar, or the sal-ammoniac mountain. The bulk of the article found in commerce is, however, an artificial product, the sources of which will be more intelligibly described at the close of this section.

If to this muriate of ammonia we add sulphuric acid, the salt is decomposed, and dry muriatic acid gas is disengaged, and may be recognised by the characters given at page 91. But if the salt be mixed in a retort with newly burnt lime, (oxide of calcium,)—a gas which I have not as yet described, is evolved in great abundance on the application of a gentle heat. This gas is termed Ammonia. It is colourless, extremely volatile, has a strong pungent smell, and affects the eyes very painfully. It is so very soluble in water and alcohol, that it must be collected over mercury or by displacement. In its pure state it is so irritating that it cannot be respired, but when much diluted with air, it may be breathed with safety, indeed often with advantage. It extinguishes flame, and is not combustible itself, but when decomposed by heat its hydrogen takes fire.

In collecting ammoniacal gas by displacement, it is necessary to place the receiving vessel above the retort or flask in which the materials are mixed, as shewn in *fig.* 19; as 100 cubic inches of ammonia weigh but 18 grains, it is much lighter than atmospheric air, and ascends to the top of the vessel.

Ammonia in its gaseous state, or when dissolved by water, is powerfully alkaline. It unites with and neutralizes acids, forming salts. It restores the blue colour of litmus paper previously reddened by an acid; it changes the yellow colour of turmeric to a deep reddish brown.

The composition of ammonia has been ascertained by very conclusive experiments. By conducting 100 cubic inches of it through porcelain tubes heated to redness, or by exposing the same volume to a succession of electric sparks, there result 150 measures of hydrogen and 50 of nitrogen, which in the ammonia, while chemically united, occupy but the space of 100 measures. Ammonia is consequently composed of one eq. of nitrogen and three of hydrogen, both by weight and volume; its combining equivalent is 17 on the hydrogen scale, and its specific gravity rather more than one-half that of atmospheric air.*

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* A different view of the composition of ammonia is now entertained by many chemists of great eminence. It will be explained in the introduction to the part of this volume which treats of organic chemistry.

Water absorbs 780 times its bulk of this gas, and the specific gravity of the solution is 0·875. This solution is commonly termed *liquid ammonia*, is an invaluable remedy, and may be thus prepared.

If powdered muriate of ammonia be mixed with an equal weight of fresh burned lime, previously made into a thin paste with water, and the mixture be heated in the simple apparatus, described at page 92; the lime unites with the muriatic acid of the salt, forming neutral muriate of lime, and gaseous ammonia will be extricated in great abundance, and dissolved by the water in the receiving bottles. This solution possesses all the characteristic properties of the gas itself. It boils at 130°, giving out gaseous ammonia so freely, that this method is the best for preparing small quantities of the gas for experimental purposes.

If gaseous ammonia be mixed in a glass vessel with the vapours of muriatic, nitrous, acetic, sulphurous or any other volatile acid, a salt of the acid and ammonia is immediately formed in dense fumes composed of minute crystals, which soon arrange themselves on the sides of the vessel. If a small quantity of ammonia be mixed with chlorine, it is at once decomposed, and muriatic acid and nitrogen are formed; if the ammonia be in excess, muriate of ammonia is produced.

If strong spirit be substituted for water in the receiver, in the experiment above described for the preparation of the solution, a very powerful stimulating liquid is obtained, of much importance to the medical practitioner. This is called ammoniated alcohol.

SALTS OF AMMONIA.

As the elements of ammonia (hydrogen and nitrogen) exist in large quantities in all animal and some varieties of vegetable matter, so we find that the decay of such substances produces large quantities of this gas, sometimes uncombined, but much more frequently associated with the carbonic, sulphuric, or muriatic acids. Thus during the combustion of coal, sulphate of ammonia is formed and condenses with the soot, from which it may be readily removed by washing with water. When animal matters are steeped in a solution of muriate of magnesia, (see that head,) and then slowly burned, muriate of ammonia sublimes.

In various parts of Hindustan, of Asia Minor, and in Africa, *Muriate of Ammonia* is obtained in considerable quantities by heating camel's dung, in which it exists already formed. In Europe the process by muriate of magnesia is had recourse to; or common salt (muriate of soda) is decomposed by sulphuric acid, and the muriatic acid gas conducted into chambers where animal matter is undergoing decomposition or slow combustion. In another method the soot of coal is deprived of its sulphate of ammonia by washing, and the product is heated to redness with common salt; muriate of ammonia sublimes, and sulphate of soda remains.

Sulphate of ammonia may be prepared for experiment by decomposing muriate of ammonia by sulphuric acid.

The *Nitrate of ammonia*, so much used in the preparation of the "laughing gas," may be made by mixing dilute nitric acid with the carbonate of ammonia, until no effervescence occurs, and until the solution does not affect blue vegetable colours. On evaporation to dryness at a temperature of 212°, a mass of fibrous crystals is procured. The mode of obtaining nitrous oxide from this salt has been described at page 35. If the salt be heated to 600°, it explodes violently, being changed into water, nitrous acid, nitric oxide, and nitrogen.

The *Carbonates of ammonia* are three in number, one of which, the first described, is important in medicine, and in various chemical processes.

The *Sesqui-carbonate*, (or what is sold as the carbonate in the shops,) is prepared by heating a mixture of one part of muriate of ammonia and one and half parts of carbonate of lime, (chalk.) Sesqui-carbonate of ammonia sublimes, and dried muriate of lime, (chloride of calcium,) remains in the vessel.

This process is rather difficult on the small scale. In larger operations the mixture should be made in an iron pot, with a wide pipe, six inches in diameter, attached to it, made of sheet iron, about four feet long, and running horizontally through a trough supplied with cold water. The salt which concretes in the pipe is hard, transparent and crystalline, having a strong ammoniacal smell. It is composed of two equivalents of ammonia and three equivalents of carbonic acid.

The *Carbonate of ammonia* is a rare salt, and can only be prepared by mixing dry carbonic acid over mercury with twice its volume of ammoniacal gas. It is composed of one equivalent of each of the ingredients.

The *Bi-carbonate* is formed by passing a current of carbonic acid gas through a solution of the sesqui-carbonate. The resulting salt has but little smell or taste, and contains one equivalent ammonia and two of carbonic acid.

The *Acetate of ammonia* is prepared by neutralizing the common carbonate of ammonia by distilled vinegar, (acetic acid). Two ounces of the salt and four pints of vinegar may be employed. The acetate of ammonia should be kept in solution. It is an excellent sudorific and diuretic medicine.

The *Hydro-sulphuret of ammonia* is much used as a chemical test for various metals, especially arsenic, antimony, lead, silver, &c. It is prepared in solution by passing a current of sulphuretted-hydrogen gas through water of ammonia. The solution readily attracts oxygen from the air, a sulphate of ammonia being produced, and it consequently must be preserved in well-stoppered bottles.

SECTION XVI.

COMPOUNDS OF CARBON AND HYDROGEN—LIGHT CARBURETTED HYDROGEN OR FIRE DAMP—THE SAFETY LAMP—OLEFIANT GAS—ETHERINE, ALCOHOL AND SULPHURIC ETHER—BICARBURET OF HYDROGEN—CAMPHENE, CITRENE, AND THE ESSENTIAL OILS—THE ILLUMINATING GASES OBTAINED FROM COAL AND OIL.

The compounds of carbon and hydrogen are fraught with interest to mankind, as the subjoined sketch will sufficiently point out and illustrate.

The first of the series occurs naturally in vast quantities. It is formed during the decomposition of vegetable matter under water, and may be collected readily by merely stirring the mud at the margin of a tank, and receiving the bubbles in an inverted bottle. It is a colourless transparent gas, free from acid or alkaline properties. It is a non-supporter of combustion, and is highly inflammable itself, burning with a yellow flame. 100 cubic inches weigh 17½ grains, and are found to consist of 200 cubic inches of hydrogen and 100 cubic inches of vapour of carbon. Hence if exploded with oxygen, 200 measures of this gas are consumed, 100 oxygen converting 200 hydrogen into water, and 100 oxygen uniting with 100 vapour of carbon to form 100 carbonic acid.

The *fire-damp* of coal mines is chiefly composed of this gas, but there is also present variable proportions of carbonic oxide, simple hydrogen and sulphuretted hydrogen and other gases. As light carburetted hydrogen requires twice its volume of oxygen to form water and carbonic acid, hence 100 cubic inches will require nearly 1,000 of common air to afford them the necessary quantity of oxygen, and with this quantity it explodes violently, but with smaller proportions of air the mixture is moderately explosive still.

It is remarkable that while mixtures of common air and some inflammable gases, such as carbonic oxide and hydrogen, take fire readily on contact with a red-hot substance, the light-carburetted hydrogen and air do not explode unless the heated body be actually inflamed. These facts are, however, easily explained. Tranquil flame is gaseous matter heated to a degree far beyond that of the ignition of solid bodies. Thus, if a piece of gauze made of very fine iron or brass wire be placed over a flame, in the mode shewn in *fig.* 20 the flame does not ascend through the wires. Passing through the wire-gauze cools the gaseous matter to a degree below that of flame. But if a taper be applied to the heated air issuing through the meshes immediately above the intercepted flame, this at once takes fire.

From the preceding data the student can without difficulty understand the nature of the celebrated "safety lamp" which Sir Humphrey Davy constructed for the preservation of miners from the dreadful calamities to which they are exposed by the casual explosion of the fire-damp. *Fig.* 21 is a drawing of the Davy lamp. It is simply a cage of fine wire-gauze enclosing an ordinary oil-lamp. When the miner reaches an explosive atmosphere, the gases penetrating within the cage inflame immediately, but the flame merely plays on the inner side of the cage, and, for the reasons above described, does not extend to the outer atmosphere. As soon as the flame enlarges, the miner is warned to escape, for delay may cause the fire gauze to be burned through, when the flame would pass and explosion forthwith occur.

Though under circumstances exactly such as we have above described, the safety lamp well deserves its name, still it is an extraordinary fact that, taking a period of fifteen years before and after the invention, the loss of life in the English mines is as great in the second as in the former period. A Committee of the House of Commons was recently appointed to investigate this subject, and in the course of their inquiries it was found that the lamp might cause explosion, if the fire damp is driven against it in a strong current—or if a particle of coal or other inflammable substance comes in contact with the outer side of the gauze, and is inflamed—or if sulphuretted hydrogen or pure hydrogen is present in any considerable proportion. Against the two former of these contingencies a glass cover to the lamp is a sufficient precaution. The last source of danger is one which I fear no ingenuity can overcome.

The next compound to be described, is the

OLEFIANT GAS,

so called because when mixed with *chlorine* it forms a fluid resembling oil (*oleum*, oil *fit*, is made, Latin). It is composed of 2 eq. carbon and 2 eq. of hydrogen. It is prepared by mixing two measures of strong sulphuric acid with one of alcohol, and heating the mixture by a lamp. Alcohol is composed of carbon, hydrogen, and oxygen in the following proportions:—

Carbon, eq:	2	which yield	Carbon, ...	2	olefiant gas.
Hydrogen, eq: ...	3		Hydrogen, ...	2	
Oxygen, eq:	1		Hydrogen, ...	1	water.
			Oxygen, ...	1	

The water unites with the sulphuric acid and the olefiant gas is set free. Mr. Ritchie has lately given additional proof of the correctness of this view by decomposing alcohol by a galvanic battery, when olefiant gas and water were evolved at the opposite electrodes.

As the proportions of acid and spirit above given are not in the exact atomical ratio required, it always happens that a portion of alcohol deposits its carbon in the solid black state, forming a thick mass in the retort. This carbon decomposes some sulphuric acid; and sulphurous and carbonic acid gases are evolved and absorbed by the water over which the olefiant gas is collected.

Olefiant gas is colourless, tasteless, and inodorous when pure, irrespirable and a non-supporter of combustion, but burning itself with a rich white light. If 100 measures are exploded with oxygen by the electric spark, 300 measures of oxygen are consumed; water is deposited, and 200 measures carbonic acid formed. Olefiant gas must consequently consist of two volumes of hydrogen and two of carbon vapour condensed into one; 100 cubic inches must therefore weigh 30½ grains, the specific gravity being less than that of atmospheric air.

A very striking experiment may be made by mixing two measures of chlorine and one of olefiant gas in a glass jar and applying a light. The gaseous mixture burns rapidly, and black clouds of finely divided carbon are formed. But if the gases are left together for some time, and no heat applied, they combine directly, and the characteristic oily-looking compound collects in large globules. This is a chloride of hydrocarbon, and if exposed to the direct rays of the sun in contact with chlorine, muriatic acid gas and per-chloride of carbon are formed. This per-chloride (*see page* 96) is a white crystalline solid, of an odour resembling camphor, and readily decomposed into chlorine and carbon.

The olefiant gas combines with chlorine in this manner as well in the dark as when exposed to the sun's rays. Light carburetted hydrogen is also decomposed by chlorine, muriatic acid and other gases being formed, but this effect only occurs under the direct rays of the sun.

ETHERINE.—(C^4, H^4.)

This is a compound of 4 eq. carbon and 4 hydrogen, of much practical and theoretical importance. It is obtained during the compression of oil or coal gas for the purposes of illumination, as subsequently described. In this process a volatile liquid collects, which boils at 60° Fahrt. From this the etherine is obtained in vapour at a temperature below the freezing point of water. On condensing the vapours by extreme cold a liquid is formed, which is the lightest of all known solids or liquids, its density compared to water being as 627 to 1000.

100 cubic inches of the vapour weigh 61 grains, and require 600 cubic inches of oxygen to be converted into 400 carbonic

acid and watery vapour. It is extremely combustible, and burns with a fine white flame.

It is worthy of especial attention, that the proportions of carbon and hydrogen in this compound are in the same ratio to each other 4 C.—4 H. as in the olefiant gas, 2 C.—2 H. Hence alcohol may be considered as composed of one eq. olefiant gas (two carbon, two hydrogen) and one of water; or it may be regarded as a compound of one eq. etherine (four carbon, four hydrogen) and two of water. The latter view is rendered probable by the circumstances connected with the preparation of the well-known and valuable liquid the sulphuric ether.

PREPARATION OF SULPHURIC ETHER.

Equal weights of strong sulphuric acid and alcohol are cautiously mixed in a capacious glass retort, pouring the acid slowly in after the alcohol in a very thin stream, and shaking the mixture repeatedly. Great heat is evolved, and on applying heat very cautiously the liquid soon boils. Ether is generated, and may be collected in a receiver kept cold by wet towels. When as much ether as is equal to half the volume of the alcohol employed is collected, sulphurous acid commences to be disengaged in copious white clouds, and the process may then be discontinued. If persevered in, olefiant gas comes over, in large quantities.

The ether in the receiver at first contains some alcohol and sulphurous acid, from which it may be freed by mixing it with a solution of potash in water and distilling a second time. When thus purified, ether is a transparent, colourless, very volatile and inflammable liquid, which boils at 96°; a common temperature of the air in this climate. Its density when properly prepared is 735°. It is soluble in alcohol in all proportions. Water retains about a tenth of its volume. Its vapour when mixed with oxygen explodes violently when inflamed.

The composition of ether has been accurately ascertained to be, carbon 4 eq., hydrogen 5 eq., oxygen 1 eq.—Thus it may be regarded as a compound of one eq. etherine (4 C.—4 H.) and one of water. Alcohol, as I have before stated, may be considered a compound of one eq. etherine and two eq. water; thus ether and alcohol may be appropriately named, *ether* the proto-hydrate, *alcohol* the bi-hydrate, of etherine.—For the nature of hydrates see page 32.

According to the theory of Berzelius and Liebig, now adopted by Graham and most modern chemists, the elements of ether are thus arranged. C_4. H_5. constitute a basic principle *(ethyle,)* capable, like cyanogen, of uniting with oxygen and other simple bodies. Ether is thus an oxyde of ethyle, C_4. H_5. O. Ethyle neutralizes acids—with 1 eq. of water it forms alcohol C_4.—H_5. + H. O. These views will receive further exposition as we proceed.

The sulphuric ether is of great value in medicine, and in various chemical processes, especially in the analysis of vegetable or animal matter. The student will recollect that its name does not indicate its composition, since it contains no sulphur. The name is derived solely from its mode of preparation, and it is accordingly found that the phosphoric acid, chloride of zinc, and many other substances having a strong affinity for water, can decompose alcohol and generate this compound. Further remarks on the constitution of some other ethereal compounds used in medicine occur in another part of this volume.

BI-CARBURET OF HYDROGEN, OR BENZULE.

This is a colourless liquid compound, obtained also during the compression of coal gas. Its density is less than that of water, its boiling point 136°. It is composed of 6 eq. carbon and 3 hydrogen, and 100 measures of its vapour require 750 of oxygen for their complete conversion into water and carbonic acid. Bi-carburet of hydrogen may also be prepared very easily by distilling three parts of lime with one of benzoic acid (see that head) in a glass retort. Benzoic acid is composed of 14 carbon, 6 hydrogen, 4 oxygen. On distillation with lime, 2 eq. of bi-carburet of hydrogen or benzin (3 hydrogen, 6 carbon) come over, and 2 carbonic acid (1 carbon, 2 oxygen), unite with the lime.

Naphtha, the *neft* نفط of the Arabs, and *mati ká tel* متي كا تيل of the Hindus, is another remarkable liquid compound of 6 carbon, and 5 hydrogen. It occurs in vast quantities in natural springs in Persia, Arabia, and the Burman empire, in Italy, the West Indies, and a variety of other localities. It is also artificially procured in abundance and purity during the distillation of coal for the manufacture of gas on the large scale. As it contains no oxygen it is much used for preserving potassium, sodium, and similar highly oxydizable substances. It is valuable in domestic economy as a substitute for oil; it dissolves caoutchouc (see that head), with which it forms an excellent water-proof varnish; and, lastly, it is not devoid of utility as a medicinal agent.

Naphthaline is a white solid substance produced during the distillation of coal. It forms some curious compounds with chlorine and sulphuric acid.

Camphene is an oil of turpentine in its purest state, composed of 10 carbon and 8 hydrogen. With one equivalent of oxygen it forms the well-known substance named Camphor: with 2 eq. oxygen it forms camphoric acid. Camphene, moreover, seems to be the basis of most volatile oils. With muriatic acid it forms a perfectly neutral compound called artificial camphor.

The volatile oil of lemons, also termed *Citrene,* is composed exclusively of carbon and hydrogen, in the proportions of 5 carbon and 4 hydrogen, the same proportions but half the quantities of the elements of camphene.

The series of carburets of hydrogen with reference to their important bearing on the theory of organic compounds, is given in the introductory notice of Organic Chemistry.

Besides the preceding substances there are several other liquid and solid carburets of hydrogen,—such as *eupione*, an oily liquid, obtained from wood-tar, and *paraffine*, a crystalline solid procurable from the naptha of Rangoon; but the consideration of these substances scarcely falls within the limits of this volume.

ILLUMINATING GASES OBTAINED FROM OIL AND COAL.

This is a topic replete with interest, especially to the Indian student, the more so, since he can readily imitate, by cheap and simple though beautiful experiments, the admirable processes by which the chief cities of Europe now glow at midnight with a brilliancy approaching to that of the day itself.

When coal is heated in an iron or earthen retort, or when oil is dropped on a surface heated to low redness, decomposition ensues, and hydrogen, carbonic acid, carbonic oxide, nitrogen, the light carburetted hydrogen, olefiant gas, and the vapours of the heavy carburets, are disengaged in the gaseous state. Generally the hydrogen and nitrogen form ammonia; and, as most kinds of coal contain sulphur, it commonly happens that sulphuretted hydrogen and sulphurous acid gases are mixed with those above mentioned. Of these gases, hydrogen and carbonic oxide evolve but little light during their combustion: the nitrogen and carbonic acid are incombustible and prejudicial; the sulphuretted hydrogen burns with a feeble flame, but is extremely poisonous, and also injurious to paintings, plate, &c. Hydrogen, nitrogen, and carbonic oxide, however, occur but in very minute proportions, and the carbonic acid, sulphurous acid, and sulphuretted hydrogen, are absorbed by passing the mixed gases through a solution of lime.

The value of the purified gas as an illuminating agent depends on the quantity of olefiant gas, and the vapours of the heavy carburets which it contains. This may be estimated by the density of the gas, which in practice is very difficultly obtained—by the quantity of oxygen required for the conversion of the gas into water and carbonic acid—or, lastly, by the proportion absorbed by chlorine *in the dark.* The pupil will remember that chlorine does not act on carbonic oxide or on light carburetted hydrogen, unless light be admitted.

On the enormous scale required for the illumination of a great city, large iron cylinders are filled with coal and heated in furnaces to low redness. The disengaged gases are led through water into a reservoir termed the *hydraulic main.* In this the tar and ammonia are retained, and from thence the gases pass through a purifying chamber containing layers of slaked lime, or hay sprinkled with moistened or powdered lime. By this the carbonic acid, sulphurous acid, and sulphuretted hydrogen are separated. The purified carburets of hydrogen now ascend through a pipe into a gasometer of immense dimensions (generally 20,000 cubic feet), so constructed that it rises and falls in a tank containing water. Lastly, from this gasometer issues a central pipe of cast iron well flanked and cemented, and branch pipes again convey the gas in every possible direction.

Thus by the triumphant hand of the chemist and engineer, streams of ready fuel and sources of the brightest light are guided through every street of our noble towns. In the depths of the lowest cellar, and to the summit of the loftiest tower, the pliant vapour is distributed. The sun has scarcely set when our cities blaze with a rival light, and steadily and tranquilly does this shed its beams till the return of day renders the illumination needless.

All these magnificent phenomena are procured at so cheap a rate, that the old and obscure plan of lighting was dearer to a great degree. The question has been started as to the feasibility and advantages of illuminating Calcutta in this manner. The Burdwan coal I have found by actual experiment to be as productive of a fine illuminating gas, as the best coal which England produces; a point of no small importance, because varieties of coal differ greatly in the quantity and quality of their gaseous products. We might also, it is true, smelt our iron and cast our pipes on the spot, and native engineers could readily be trained to the manipulations of the business. But I fear the probable consumption of the gas would not for many years pay even the interest on the capital sunk in the undertaking. I venture to give this opinion in consequence of having examined with attention the documents connected with an actual plan to effect the object in view. It must be remembered that we have in Calcutta no great and constant demand for the article, like that created by the London theatres, and the various factories and establishments where business is carried on by night as well as by day. Our European shops, moreover, close at sunset, and the native tradesman can scarcely be convinced that it is expedient to burn a light, the lamp for which will cost him more than would supply him with a year's oil. When we add to these considerations the extreme cheapness and excellence of the oils in this country, and the more advantageous openings which present themselves on every side for the investment of capital, it can scarcely be expected that Calcutta can for many a year shine in this artificial light.

It may, however, be found desirable to adopt this mode of illumination in some private establishments or in the mansions of wealthy native gentlemen. In such cases I would recommend the use of oil gas, as it is more easily prepared, and does not require the purification to which coal gas must be subjected. As the oil of mustard contains sulphur, any of the other oils may be preferably employed. The oil is dropped through a tube into an iron vessel containing pieces of charcoal or coke (carbonized coal) and heated to low redness. The gas is led at once through an iron pipe to a small gasometer of sheet iron about six or eight feet square, playing in a water tank built of masonry. Leaden pipes may be used to lead the gas wherever it may be required, and Argand burners with stop-cocks may be employed with most economy and advantage. A gasometer such as that I now describe, will contain from 216 to 512 cubic feet of gas. Each single jet of gas burns 2½ cubic feet per hour, giving a light equal to nine wax candles of 10 to the seer. The gasometer may be filled in two hours. The gas improves by being kept over water, so that one charge of the reservoir might last for several days. The gasometer may, of course, be made much smaller than that described, and instead of oil, bruised linseed or castor oil cake, or similar substances, may be substituted.

To enter on minute details would be inconsistent with the objects and dimensions of this little treatise, but I will willingly give any further information in my power to persons desirous of constructing domestic gas works.

SECTION XVII.

CYANOGEN GAS, OR THE BI-CARBURET OF NITROGEN.

($N. C_2$.)

This curious and important gas was discovered by Gay Lussac in 1815. It derives its name from the Greek words *cyanos*, blue, and *gennao*, I generate, in consequence of its entering into the composition of the well-known Prussian Blue. Although proved to be a compound gas, Cyanogen still combines directly with metals and some other simple substances. From one of these compounds the bi-cyanuret of mercury, (the mode of preparing which is described in this section,) the cyanogen is most readily procured by heating it in a very small retort of glass or iron. Before commencing the process, care must be taken that the cyanuret of mercury is perfectly dry. On applying heat by a spirit lamp, the cyanuret of mercury becomes brown and black, and the gas is rapidly disengaged. It is transparent and colourless, of a strong and unpleasant smell, soluble in one-fourth its bulk of water, and one-twentieth its bulk of alcohol. Its specific gravity is 1,800, nearly twice that of atmospheric air. Hence it must be collected over mercury, or by displacement, like the carbonic acid. It is fatal to animals, and extinguishes flame. Cyanogen burns with a fine crimson flame, and if 100 measures be mixed with 200 of oxygen and inflamed by the electric spark, 200 measures of carbonic acid are formed and 100 nitrogen remain. Hence the gas is composed of two equivalents carbon and one equivalent nitrogen, and its combining proportion is represented by the number 26.

The compounds which cyanogen forms with hydrogen, oxygen, sulphur, and some of the metals, especially potassium, iron, and mercury, are of such great importance in medicine, in toxicology, and in the arts, that I shall describe them in minute detail, commencing with the metallic compounds.

CYANURET OF POTASSIUM.

This is formed whenever animal matter is heated to low redness with potash. It occurs in cubic colourless crystals, soluble in water and alcohol. When dissolved in water it is converted by the hydrogen and oxygen into hydro-cyanic acid and oxide of potassium, and if any acid be added the hydro-cyanic acid is expelled. It is an extremely poisonous substance. It is composed of one equivalent of cyanogen and one equivalent of potassium.

With one equivalent of iron and one of potassium, two of cyanogen unite to form one of the most valuable substances known in chemistry or the arts, and called correctly

THE FERRO-CYANURET OF POTASSIUM,

or familiarly Prussiate or Ferro-cyanate of Potash. In this interesting salt, one equivalent of cyanogen and one equivalent of iron act the part of an acid, the base being composed of one equivalent of cyanogen and one equivalent of potassium. It is prepared easily, and in abundance by heating together to low redness, in a deep iron pot, a mixture of dried animal matter with half its weight of carbonate of potash, and one-third of iron filings, turnings or clippings of sheet iron. Very offensive inflammable vapours are disengaged, and after the mixture has cooled, by washing the powdered mass with water the salt in question is dissolved out. It concretes on evaporation in large, transparent, semi-elastic, lemon-coloured crystals, insoluble in alcohol, very soluble in water, devoid of odour, of slightly bitter taste.

When well dried and heated to redness in a close vessel, the cyanuret of iron of this compound is decomposed, nitrogen being evolved, and carburet of iron remaining along with cyanuret of potassium which escapes decomposition. By acting on the residuum with a small quantity of cold water, pure cyanuret of potassium is obtained in large quantities.

When the ferro-cyanuret of potassium is dissolved in water, it may be considered to associate with the elements of water, so as to form two equivalents of hydro-cyanic acid, one equivalent of oxide of potassium, and one equivalent of protoxide of iron, both which bases combine with the acid.

There is another compound of iron, cyanogen, and potassium called the

FERRO-SESQUI-CYANURET OF POTASSIUM.

This is prepared by passing a current of chlorine gas through a weak solution of the salt above described. The chlorine abstracts one equivalent of potassium from every two equivalents of the salt. This compound may be obtained in fine red crystals soluble in water. It is of much value as a test for the Proto-salts of iron, with which it forms the following well known blue substance.

THE PRUSSIAN BLUE.—(CYANURET OF IRON.)

The researches of Berzelius have very recently terminated the controversy so long waged as to the composition of this celebrated substance, which was accidentally discovered in Berlin in 1792.

If a solution of the ferro-cyanuret of potassium be mixed with a solution of muriate or sulphate of the *per*-oxide of iron, a rich blue precipitate falls down, which consists solely of six equivalents cyanogen and five equivalents iron, arranged in such proportions that three equivalents of cyanogen and three of iron constitute a *proto-cyanuret of iron;* and three of cyanogen and two iron form the *sesqui-cyanuret of iron, both which compounds are essential to the formation of Prussian Blue.* This may be rendered more intelligible by the subjoined diagram.

Reaction of Ferro-cyanuret of Potassium on the Per-oxide of Iron to form Prussian Blue.

3 eq. Ferro-cyan. Potassium, contain	2 eq. of Per-oxide Iron, contain
6 Potassium*,	6 Oxygen*,
6 Cyanogen†,	4 Iron†.

3 Iron,
3 Cyanogen, } undecomposed proto-cyanuret of iron.‡

These form

* 6 eq. Potassa.

† Sesqui-cyanuret of Iron, which with the undecomposed Proto-cyanuret of Iron ‡ forms Prussian Blue.

Were the protoxide of iron substituted for the *per*-oxide, the blue substance could not be formed; for a sufficient proportion of oxygen not being present, the potassium could not be separated to the same degree, and no sesqui-cyanuret could be produced.

The ferro-*sesqui*-cyanuret of potassium, on the contrary, produces the requisite interchange only with the *proto*-salts of iron, and this with such delicacy that it will detect one part of protoxide of iron in 90,000 of water: Thus—

Reaction between Ferro-sesqui Cyanuret of Potassium and Protoxide of Iron.

2 eq. Ferro-sesqui Cyanuret of Potassium, contain	6 eq. Protoxide of Iron, contain
6 Potassium,*	6 Oxygen,*
6 Cyanogen,†	6 Iron.†
2 Iron,‡	
3 Cyanogen,‡	

Which form

* 6 eq. Oxide of Potassium.
† Proto-Cyanuret of Iron. } Prussian Blue.
‡ Sesqui-Cyanuret of Iron. }

The proto-cyanuret of iron is of an orange-yellow colour. The sesqui-cyanuret of iron has not been obtained in the separate state: together they constitute the rich blue dye, which is prepared on the large scale by fusing animal matters with common potash, dissolving the residuum and mixing the solution with proto-sulphate of iron and alum, (a ter-sulphate of alumina and potash.) A dirty green precipitate takes place, consisting of protoxide of iron, alumina, and proto-cyanuret of iron, which last gradually parts with a portion of its iron to the oxygen of the air, so that the essential mixture of proto and sesqui-cyanuret of iron is generated.

The Prussian blue of commerce thus contains alumina and other impurities from which it may be freed by washing with water acidulated with very dilute sulphuric acid—or it may be obtained pure directly by mixing a solution of ferro-cyanuret of potassium with a neutral solution of the *per*-oxide of iron in muriatic or sulphuric acid. When pure, the Prussian blue is insoluble in water and alcohol. It is dissolved in strong sulphuric acid, in which it forms a white gelatinous mass. Potash or soda decompose it completely, forming nitrogen, carburet of iron, per-oxide of iron, and ferro-cyanuret of potassium. Hence stuffs dyed blue by this substance cannot be washed in soap ley without losing their colour—an almost insuperable obstacle to the substitution of

Prussian blue for indigo, about which so much has been recently written.

When pure Prussian blue is heated to redness in a glass tube with a fine opening, and then the tube sealed, carburet of iron remains, and is formed in such a state of division that when the tube is broken the solid carburet becomes red hot, however long it may have been prepared. The preparation of this *pyrophorus*, as it is termed, is a good lesson in glass-working and adroit manipulation, which should not be lost on the practical student. Very minute particles of the pure Prussian blue will be sufficient for each experiment.

I have endeavoured, in the preceding sketch, to proceed step by step in the unravelling of some of the most intricate of all chemical propositions. It will materially facilitate the comprehension of the entire to make experiment go hand in hand with the study of the theoretical statements. The student will thus clearly see what he can otherwise but with great difficulty understand. The materials are extremely cheap, and the processes easily conducted. Moreover, the theoretical knowledge thus acquired will simplify most of the subsequent details.

BI-CYANURET OF MERCURY.

This is the compound employed in the preparation of cyanogen gas, and of the hydro-cyanic or Prussic acid, as we shall subsequently find. It is obtained by boiling eight parts of pure Prussian blue in thirty of water, and adding eleven of the peroxide of mercury, until the blue colour of the mixture disappears. The sesqui-cyanuret of iron is decomposed. One equivalent of cyanogen is converted into carbon and nitrogen, two equivalents of cyanogen unite with one of mercury to form the bi-cyanuret of that metal; one of iron becomes oxydized by the oxygen previously associated with the mercury, and the second equivalent of iron combines with the carbon of the decomposed cyanogen.

The bi-cyanuret of mercury is dissolved by the water, and if the mixture be filtered, carburet and per-oxide of iron, and an equivalent of *proto-cyanuret of iron remain on the filter.* The process is hence far from economical on the large scale. Where the yellow ferro-cyanuret of potassium can be had, as it may, in any quantities, in all manufacturing towns, it is better to prepare hydro-cyanic acid with sulphuric acid, as subsequently described, and dissolve in this the per-oxide of mercury, evaporate and crystallize.

The bi-cyanuret of mercury occurs in slender prisms, composed of two equivalents cyan. = 52 and one equivalent mercury = 202, total 254. It is a powerful acrid poison, soluble in water and in alcohol. When we employ it in the preparation of cyanogen, it must be perfectly dry, otherwise its moisture gives rise to the production of carbonic acid, nitrogen, Prussic acid and ammonia, instead of the gas desired.

THE HYDRO-CYANIC, OR PRUSSIC ACID.

This acid, so remarkable for its violence as a poison, and its virtues as a medicinal agent, is composed of one equivalent of cyanogen and one equivalent of hydrogen. It exists in a great number of vegetable substances, either naturally, as in the roots of the Rowan ash tree and leaves of the laurel, or being produced when the substance is heated along with water. Thus the bitter almond, when made into a paste with water, generates a large quantity of hydro-cyanic acid, although none exists in the almond before the water is added. It is often produced too during the decomposition of animal matter, especially of cheese.

To the chemist, the hydro-cyanic acid is known in two conditions—the first, the *anhydrous* or pure; the second, the solution of the pure acid in water. The anhydrous acid may be prepared easily by passing a current of sulphuretted hydrogen gas through a tube placed horizontally, and containing bi-cyanuret of mercury in coarse powder. Black sulphuret of mercury and hydro-cyanic acid are formed, and the latter passes in vapour into the receiver, which should be kept cold by a mixture of ice and salt. This process was invented by Vauquelin, and the apparatus is represented in *fig.* 22.

Another mode of preparing the anhydrous Prussic acid, is by acting on the bi-cyanide of mercury with thrice its weight of strong hydro-chloric acid. The hydrogen and cyanogen form Prussic acid, and bi-chloride of mercury (corrosive sublimate) remains in the retort, dissolved in the water of the muriatic acid. As in the former process the receiver must in this experiment be kept cold by ice and salt.

This acid thus prepared is a colourless liquid, of strong and peculiar smell, sp. gr. 705, boiling at 80° F. and evaporating with such rapidity, that if a drop be exposed to the air, the evaporation of part causes the congelation of the rest. But of all the properties of Prussic acid, its power as a poison is the most remarkable. A single drop proves instantaneously fatal to a large animal; its vapour incautiously inhaled during experiment, even though largely diluted with common air gives rise to the most alarming symptoms, and consequently the process above described should never be repeated by an inexperienced person, in warm weather or close apartments, and indeed should seldom be attempted by even expert chemists unless a trust-worthy assistant is present. Should any accident occur, the vapour of ammonia or chlorine should be applied immediately to the nostrils. The former by its physiological stimulating properties counteracts the depressing effects of the poison; the latter chemically decomposes it, combining with its hydrogen, and setting its nitrogen free.

The hydro-cyanic acid does not decompose carbonates, and does not completely neutralize potash or soda. 100 measures of its vapour are composed of 50 hydrogen, 50 cyanogen, the density is consequently 0.947. When decomposed by galvanism, cyanogen goes to the anode or positive pole, hydrogen to the cathode or negative. By being passed through a red hot porcelain tube carbon is deposited and hydrogen and nitrogen disengaged.

Owing to its extraordinary narcotic or sedative properties the hydro-cyanic acid has been administered by physicians in various spasmodic and inflammatory diseases, and often with the best effects. The concentrated acid, however, is not employed for this purpose. A dilute acid is used, for the preparation of which many processes have been devised.

MEDICINAL PRUSSIC ACID.

By passing a current of sulphuretted hydrogen through water containing a certain weight of bi-cyanuret of mercury in solution, the same decomposition ensues as in Vauquelin's process, and dilute hydro-cyanic acid, but of very variable quality, is procured.

By distilling one part of the cyanuret of mercury, one of muriatic acid, and six of water, and collecting in the receiver 6 parts of the product, the English Apothecaries' Company prepared their standard acid, which has the density of 0.995.

Dr. Clarke has recently described a process which is highly recommended by Dr. Turner and other eminent authorities. 8¼ drachms of cyanuret of potassium are dissolved in 100 drachms of water, and to this we add a solution of 18½ drachms of tartaric acid in water. The cyanuret of potassium becomes hydro-cyanate of potassa when dissolved in water. This salt is decomposed by the tartaric acid, an insoluble super-tartrate of potash, cream of tartar, being precipitated, and a very pure hydro-cyanic acid remaining in solution.

The next process is very economical and uniform in its results. The product, moreover, can be preserved for a very long period, not being at all so liable to spontaneous decomposition as the acid prepared by the experiments above described. 20 drachms of ferro-cyanuret of potassium are dissolved in 80 of water; to this is added a mixture of 18 drachms by weight of strong sulphuric acid, and 40 drachms of water.

The water is here decomposed: its hydrogen forms prussic acid with the cyanogen; its oxygen, potash with the potassium. The acid is disengaged by distillation, and sulphate of potash and a small portion of Prussian blue remain in the retort.*

The strength of hydro-cyanic acid may be ascertained by taking its specific gravity, which is a difficult and rather uncertain method—by adding nitrate of the oxide of silver, when a cyanuret of silver is formed, 100 parts of which represent 20 of real acid—or lastly, by adding peroxide of mercury to the acid and noting how much of the acid is dissolved; one-fourth of this quantity represents the hydro-cyanic acid present. Thus the equivalent of hydro-cyanic acid is 27, of peroxide of mercury 218. Now there are 2 eq. of cyanogen in the bi-cyanuret of mercury formed; $26 \times 2 = 52 +$ hydrogen $2 = 54 — 21 = 81 — 4$.

For the detection of the acid in cases of poisoning, instructions are given in the Appendix. But it will often happen that no acid can be detected, so liable is it to undergo decomposition and give rise to new gaseous products.

ISOMERIC RELATIONS OF THE PRUSSIC ACID.

A remarkable series of illustrations of the doctrine of *isomerism* is afforded by some of the changes effected in hydro-cyanic acid, by mixing it with other acids or even with water, and exposing the mixture to heat. Previous to describing these phenomena, it is desirable, however, to make the student acquainted with a substance termed the

FORMIC ACID.

This is a compound of carbon, oxygen and hydrogen in such proportions, that it may be deemed to consist of 2 eq. carbonic oxide and one of water. It is a weak acid, of peculiar taste and smell, rather resembling the acetic acid. It is secreted in

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* *Formula of the London Pharmacopœia.*—Ferro-cyanuret of potassium 2 ounces, sulphuric acid one ounce and a half, distilled water a pint and a half. 100 grains of the acid should precipitate 12.7 nitrate of silver.

large quantities by red and white ants, from which circumstance it derives its name. Artificially it may be prepared by distilling together in a large retort 1 part of dilute alcohol or of tartaric acid with 1½ peroxide manganese, and 1½ sulphuric acid, diluted with 3 parts of water. Sugar, starch, or many other vegetable substances may be substituted for the tartaric acid.

Another and extremely beautiful and easy process for procuring formic acid is by heating crystallized oxalic acid to 300°. Oxalic acid (see that head) is composed of carbon and oxygen in such proportions that they would form carbonic oxide and carbonic acid. Hence when heated suddenly the carbonic oxide and water of the crystals form formic acid, and carbonic acid is set free. The experiment is most intelligibly made in small glass tubes bent and drawn out at the lamp into the form represented in *fig.* 23, where *a* shews the tube containing the oxalic acid; *b*, the little receiver in which the formic acid condenses; and *c*, phials filled with lime water to receive and precipitate the carbonic acid.

When this formic acid is heated with peroxide of mercury, a very interesting effect is witnessed. The carbonic oxide of the formic acid takes oxygen from the red oxide of mercury and becomes carbonic acid, which escapes with effervescence, while the mercury is reduced to the metallic state in abundant and brilliant globules.

Now when formic acid 1 eq. and ammonia 1 eq. combine to form a neutral salt, it is obvious this salt is *isomeric* with 1 eq. of hydro-cyanic acid, and 3 eq. of water; thus—

Formate of Ammonia.			*Hydro-cyanic acid* 1 *eq.* & 3 *eq. water.*		
Formic acid,	Carbon,	2	Carbon,	2	1 eq. hydro-cyanic acid.
	Oxygen,	3	Nitrogen,	1	
	Hydrogen,	1	Hydrogen,	1	
Ammonia,	Nitrogen,	1	Oxygen,	3	3 eq. water.
	Hydrogen,	3	Hydrogen,	3	

Accordingly it has been found experimentally that when solid formate of ammonia is carefully heated to 300°, hydrocyanic acid and water are disengaged.

The muriatic acid and sulphuric acid produce corresponding and equally curious effects. Thus, if very strong hydro-chloric and hydro-cyanic acid be mixed together, the whole shortly becomes a mass of white crystals, from which formic acid can be expelled by heat, and *muriate of ammonia* remains. The water of the muriatic acid with the hydro-cyanic acid first produces formate of ammonia, which is decomposed by the muriatic acid; formic acid being liberated and muriate of ammonia remaining in the solid form.

CYANIC ACID, THE URIC ACID, UREA, AND THEIR ISOMERIC RELATIONS.

There are two isomeric compounds of this name, of both of which some notice is desirable.

If ferro-cyanuret of potassium be thoroughly mixed with an equal weight of finely powdered *peroxide of manganese*, and heated in a porcelain or platinum crucible to low redness, the cyanogen and potassium of the salt are oxidized; and by treating the mass with strong and boiling alcohol, the cyanate of potassa is deposited in fine crystals as the solution cools.

If this cyanate of potassa be boiled in water, its acid is rapidly changed into *bi-carbonate of ammonia!* or if a stronger acid,—for instance the sulphuric,—be added, the same effect is produced. Ammonia remains in solution, and carbonic acid escapes with effervescence. These extraordinary changes are, nevertheless, very easily explained; for 1 eq. of cyanic acid and 3. eq. of water contain exactly the same elements as 1 eq. of bi-carbonate of ammonia; thus—

Cyanic acid and water.			*Bi-carbonate of Ammonia.*		
Cyanic acid, 1 eq.	Carbon,	2	Carbon,	2	2 Carbonic acid.
	Nitrogen,	1	Oxygen,	4	
	Oxygen,	1			
Water, 3 eq.	Oxygen,	3	Nitrogen,	1	1 Ammonia.
	Hydrogen,	3	Hydrogen,	3	

But it is with the animal principles Uric acid and Urea, that the most instructive and wonderful of these reciprocal changes take place;—wonderful in truth, since they enable the chemist to imitate with accuracy several natural processes carried on in the secreting organs of living animals. The veil is thus partially lifted from some of the mysteries of life, and promise given to the philosopher that perseverance in these grand researches will lead ere long to disclosures of still higher import.

The uric acid is secreted by the kidnies of all mammalia, by birds and reptiles, especially by birds of prey and serpents of the boa and python kinds. In man the secretion is abundant in the healthy state, and in the disease called stone, concretions, composed chiefly of this acid, often form in the bladder. The urine of the boa constrictor is a white solid, consisting of nearly pure uric acid. The concretions commonly called "chalk stones" formed in the joints in "gout," contain uric acid and soda. Many other natural sources of this acid might be enumerated.

The uric acid is insoluble in water or alcohol. It forms soluble compounds with the alkalies from which this acid is thrown down by most others. When it is moistened with nitric acid and heated, a beautiful crimson colour is produced. On analysis it is found to consist of carbon 5 eq. nitrogen 2 eq. hydrogen 2 eq. oxygen 3 eq.; thus evidently containing all the elements from which cyanogen and its compounds might be derived.

Accordingly, if dry uric acid be heated with chlorine, cyanic and muriatic acid are generated in large quantities. If heated in a retort, carbonate and hydro-cyanate of ammonia are formed, and a volatile acid sublimes called the pyro-uric or *cyanuric* acid.

The fine crimson substance formed by the nitric and uric acids is described in most works on chemistry, as a compound of uric acid called the *purpuric*, and ammonia. But the latest researches have thrown much doubt on the nature of the matter in question.

Urea is the peculiar and characteristic principle of the urinary secretion of man. It is obtained by evaporating that fluid nearly to dryness and then adding nitric acid, which forms with the urea a mass of brown crystals. These are decomposed by potash, the colour discharged by animal charcoal, and the urea purified by crystallization from boiling alcohol.

The crystals are of a pearly appearance, transparent and colourless, soluble in water and alcohol, forming fine crystalline compounds with the nitric and oxalic acids. On analysis urea is found to consist of—

Carbon 2 eq. nitrogen 2 eq. hydrogen 4 eq. oxygen 2 eq. being thus isomeric with the hydrated *cyanate of ammonia*, carbon 2 eq. nitrogen 1 eq. oxygen 1 eq.: cyanic acid—nitrogen 1 eq. hydrogen 3 eq. ammonia—and hydrogen 1 eq., oxygen 1 eq.: water.

Accordingly we find that urea, under various circumstances, yields numerous compounds of cyanogen, and these again afford us urea. Thus, heated in a retort to 248°, urea is resolved into carbonate of ammonia and *cyanuric acid*. If this cyanuric acid perfectly dried be heated strongly and the vapours collected in a receiver surrounded by a cooling mixture, a limpid colourless liquid is obtained, which is a compound of 1 eq. cyanic, and of 1 eq. water.

The cyanic acid in this state is powerfully acid and corrosive, immediately blistering the skin, extremely volatile and inflammable. If allowed to evaporate at the temperature of the atmosphere, it boils violently, and an insoluble white compound is formed, containing the same elements as the hydrous cyanic acid, and identical with the cyanuric or pyro-uric acids obtained from urea and uric acid by heat.

Now as urea yields us these compounds, conversely we can from them prepare urea. Thus if cyanic acid, however prepared, be neutralized with ammonia, on evaporating the solution pure *urea* is obtained.

Or if the cyanate of potassa (prepared by heating the ferrocyanuret of potassium and peroxide of manganese), be added to a soluble salt of lead, a white cyanate of oxide of lead is thrown down. If ammonia be added to this salt, oxide of lead is disengaged and cyanate of ammonia produced.

This salt contains the same elements as the animal principle urea, and when we evaporate the solution, *crystals of fine urea* are deposited.

THE FULMINIC ACID.

This is a well known and very powerful detonating compound, prepared by boiling 100 grains of mercury or silver in one and half ounces of nitric acid, and adding to the cold solution two ounces of alcohol. A gentle heat should be applied; effervescence takes place, and the fulminating compound is precipitated in white flocks. These are on analysis found to be composed of cyanic acid and an oxide of the metal employed. The nitrogen and oxygen are derived from the nitric acid, the carbon from the alcohol employed. It receives the name of Fulminic acid to express its detonating properties, and to distinguish it from the isomeric acid before described.

The fulminates of mercury and silver explode violently—when heated to 300°—by percussion or friction—and hence required to be made only in small quantities, and with the utmost caution. The powder should never be kept in corked or stoppered bottles.

HYDRO-SULPHO-CYANIC ACID.

If the ferro-cyanuret of potassium be mixed with an equal weight of sulphur, and the mixture be heated until it ceases to flame, a black mass results, from which by washing the water we can extract a salt of potash and the preceding acid, which is a compound of cyanogen 1 eq., sulphur 2 eq., hydrogen 1 eq. The salts of this acid are distinguished by their giving a *fine red* colour to solutions of the peroxide of iron. The hydro-sulpho-cyanate of soda exists in human saliva, in which it can be readily detected by the red colour produced on the addition of a drop or two of the per-muriate of iron.

There are several other compounds of cyanogen which I pass over unnoticed, inasmuch as they do not bear so closely on the doctrine of *isomerism*, as those I have just described, and which I am aware constitute a difficult though equally useful, lesson in chemical science.

SECTION XVIII.

THE SULPHURET OF CARBON.

This compound is prepared by passing the vapour of sulphur over pieces of good charcoal heated to redness in a porcelain tube. A very volatile limpid fluid passes over, and is received in ice-cold water, through which it subsides. Its specific gravity is 1.272. It is transparent and colourless, extremely fœtid, boils at 110°, and evaporates so rapidly that intense cold is produced during the ebullition. Mercury may be frozen on the hottest day by dropping sulphuret of carbon on a thin glass tube containing the metal.

The vapour of sulphuret of carbon explodes with oxygen, and when mixed with nitric oxide and a light applied, burns with a very dazzling pale green flame.

In this compound there are 2 eq. of sulphur and 1 eq. of carbon. The bi-sulphuret of carbon forms an extensive class of bodies called sulphur-salts, of which some examples will be subsequently described.

SECTION XIX.

LIQUEFACTION OF CERTAIN GASES BY COLD AND MECHANICAL PRESSURE—SOLIDIFICATION OF CARBONIC ACID—HYDRATES OF GASEOUS BODIES.

In this section, which concludes the view of the non-metallic elements, I propose to give a succinct account of some remarkable facts connected with the physical constitution of some of the gases I have previously described.

Every substance enumerated as a gas in the preceding sections exists in the gaseous state under ordinary circumstances of temperature and pressure, that is, when they are only heated to the mean standard of the atmosphere, and pressed on by the atmospheric column alone.

Now, while on the one hand, by elevating the temperature, or removing the pressure of the atmosphere, we facilitate the evaporation of numerous liquids, such as ether, alcohol, and water, we find that increasing the pressure, or diminishing the temperature produces exactly opposite effects on several of the gases, simple and compound.

The following gases have been reduced to the liquid state by exposing them to strong pressure, or intense cold. The pressure is expressed by the number of atmospheres, each of which represents 15 lbs. to the square inch of surface.

Sulphurous acid gas,................	liquefied by	2	atmospheres.
Sulphuretted hydrogen, ...	,,	17	
Carbonic acid, ...	,,	36	
Chlorine, ...	,,	4	
Nitrous oxide,......................	,,	50	
Cyanogen, ...	,,	3	
Ammonia, ...	,,	6	
Muriatic acid,......................	,,	40	

A description of the mode of condensation of *cyanogen gas* will give a sufficient idea of the nature of these experiments.

Cyanuret of mercury dried and powdered is introduced into a glass tube about 8 inches long, sealed at one end, and bent obliquely at 5 inches from the sealed end. The cyanuret is to fill about three-fourths of the closed limb of the tube, which is next to be drawn out at the other end also, until a fine aperture is left. A little cyanogen is then to be disengaged by heating the cyanuret, and as soon as the gas takes fire at the aperture, this is to be closed also by introducing it into the flame of a spirit lamp.

When the tube is cool, a piece of wet paper is applied to the empty limb, and the whole is supported on wires. The flame of a spirit lamp is now applied cautiously to the cyanuret. Cyanogen is extricated, and condenses in the moistened part of the tube as a transparent colourless liquid.

Sulphurous acid gas may be liquefied by introducing mercury and the strongest sulphuric acid into a tube, such as that now described, and heating the mercury.

Muriatic acid gas is condensed from a mixture of muriate of ammonia and sulphuric acid. The pressure on the interior of the tube in this instance is enormous; a tube of half an inch in diameter and 10 inches long, resisting a force of above 6,000 lbs.

Ammonia is liquefied by means of a very curious process. Dry chloride of silver at the temperature of 60° Faht. absorbs dry ammoniacal gas so eagerly, that one drachm of the chloride takes up 300 cubic inches of the gas. At 90° Faht. the ammonia is again expelled. Acting on these data, Mr. Faraday introduced this ammonio-chloride of silver into one of his condensing tubes, and speedily obtained the gas in the liquid form, which, however, it soon loses, being re-absorbed by the chloride of silver.

Chlorine when evolved in closed tubes from a mixture of sulphuric acid, peroxide of manganese, and dried sea-salt, is a yellow limpid liquid, which does not congeal at the zero of Fahrenheit's thermometer, and boils violently when the pressure is diminished.

The tubes in which the experiments of condensation have been performed are dangerous articles in a laboratory, and should never be examined unless the operator be well protected with a mask and gloves.

Hydrates of Gases.

Some of the gases above described, especially chlorine gas, form definite compounds with water,—hydrates in fact, which are very readily congealed. Moist chlorine cooled to 32° Faht. crystallizes in fine yellow needles composed of chlorine 1 eq. and water 10 eq. The sulphurous and nitrous acids afford similar results.

SOLIDIFICATION OF CARBONIC ACID.

But the most remarkable of all the experiments on the condensation of gases is that of which M. Thillorier has recently published an account. He has succeeded not only in liquefying carbonic acid, but actually in reducing it to the solid state. He collects the liquid acid and allows a jet of its vapour to escape into a phial. The sides of the phial are instantly covered with white crystals of carbonic acid, solidified or frozen by the intense cold the evaporation of part of the condensed acid produces. These experiments have been witnessed by several eminent chemists, who have all found the crystals to be the carbonic acid in a dry state.

The apparatus employed consists of a wrought iron vessel, capable of resisting a bursting pressure of 2000 lbs. to the superficial inch. Within this vessel is placed some lbs. of bi-carbonate of soda, and a vessel of sulphuric acid which can be made to discharge its contents by inverting or agitating the iron cylinder. After the materials have acted on each other for some minutes, an iron receiver is secured on by strong iron screws and bands, and a communication opened by a screw valve between the generator and this vessel. Liquid carbonic acid forms in the latter, and on allowing it to escape against a metallic cup it is converted into a solid ice.

This solid acid is comparatively of little volatility while quite dry. Mixed with alcohol or ether it disappears rapidly, producing such intense cold, that mercury, ether, and indeed all fluids, except absolute alcohol, are solidified by its contact.

The pressure is so enormous on the generating vessel, that the materials used should be of double the calculated strength; wrought or forged iron lined with lead should be exclusively adopted. While this sheet was passing through the press, we received the details of a frightful explosion of one of M. Thillorier's vessels in a laboratory in Paris. Several persons were injured, and one student killed.

PART THE SECOND.

THE METALS.

PRELIMINARY REMARKS.

In this part it is my object to give a concise description of the metals, their binary compounds and their salts; and, acting on the principle observed in treating of the non-metallic elements, minute details will be given respecting all the useful, or very remarkable substances, while all others will be passed over with a cursory notice.

Metals are distinguished from all other substances by the following properties. They are conductors of electricity and of heat. They are opaque, of a peculiar lustre, and with several simple substances they form compounds decomposable by electricity, the metal being deposited at the negative side or cathode of the electric circle.

Forty-three metals have been separated in the elementary state. They are rarely, however, found in nature in this condition, but are associated with each other, with oxygen, sulphur, and various acids, being, as it is termed, *mineralized.*

I shall not enter here into the extensive views usually inserted in chemical treatises, as to the general properties of the metals, such as their comparative densities, degree of malleability, tenacity, their mode of combination, reduction, &c. Such anticipations are generally unintelligible to the commencing, and superfluous for the experienced student. All these details will be far more appropriately placed under the respective sections treating of the individual metals.

In the following description I have adopted the classification of the metals preferred by British chemists; though the principles on which the classification reposes can scarcely be understood until the metals themselves have been accurately studied.

Class I. Metals which by oxidation produce alkalies and earths.

Class II. Metals, the oxides of which are neither alkalies nor earths.

The FIRST CLASS includes thirteen metals, which may be subdivided into three orders.

Order 1. Metallic bases of the *alkalies*:—

* Potassium—* Sodium—* Lithium.

These metals decompose water even in the state of ice, unite with its oxygen, its hydrogen being disengaged. The resulting oxides *(alkalies)*, are soluble in water, and extremely caustic, restore the blue colour of reddened litmus, and stain turmeric paper brown.

Order 2. Metallic bases of the alkaline earths, four in number:

* Barium—* Strontium—* Calcium—* Magnesium.

These also, except magnesium, decompose water at common temperatures, being oxidized and converted into the *alkaline earths*, baryta, strontia, lime, and magnesia. The three former are caustic;* and baryta, strontia, and lime are soluble in water to a considerable degree.

Order 3. Metallic bases of the earths, six in number, viz.

* Aluminium—Glucinium—Yttrium.
Thorium—Zirconium—* Silicium.

The oxides of these metals are the pure earths: they are white, insoluble in water, and do not change the colour of litmus or turmeric test papers.

The SECOND CLASS of metals includes 30. Their protoxides are often coloured, are insoluble in water, seldom affects test papers: most of the oxides unite with acids to form salts. Several of these metals, moreover, unite with oxygen and form

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* Their solutions affect test papers like the true alkalies. Magnesia only changes their colours on being applied in powder to the moistened papers.

acid compounds. They may be arranged in three orders: thus—

Order 1. Metals which decompose water at a red heat. These are seven in number:

* Manganese
* Zinc
* Iron
* Tin
* Cadmium
* Cobalt
* Nickel

Order 2. Metals which do not decompose water at any temperature, and the oxides of which are not reduced to the metallic state by heat alone. These are fourteen in number:†

* Arsenic
* Chromium
Vanadium
Molybdenum
Tungsten
Columbium
* Antimony
Uranium
Cerium
* Bismuth
Titanium
Tellurium
* Copper
* Lead

Order 3. Metals, oxides of which are decomposed by a red heat.

* Mercury
* Silver
* Gold
* Platinum
Palladium
Rhodium
Osmium
Iridium

The prefixed asterisk* denotes the metals which are most deserving our attention, from their importance in a scientific light, or for their uses in medicine, or the arts.

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† The newly discovered metal Lantanum belongs to this order.

THE METALS.

CLASS I.—ORDER I.

SECTION I.

POTASSIUM AND ITS COMPOUNDS.

Potassium has not been found in the elementary state as a natural production. It is only obtained by artificial processes, from its mineral sources, which are extremely numerous.

Thus, in combination with oxygen, potassium forms an ingredient of the mineral felspar, which exists in all granite rocks. In many varieties of granite, owing to the presence of this potash, the rock undergoes decomposition when exposed to the action of the rain and air, and the dissolved alkali is washed away to the plains.

Dr. McClelland, the author of a work of great value on the geology of Kemaon, in describing the enormous masses of detached rocks on the road between Lohúghát and Almorah, draws the following lively picture of the consequences of this reaction.

" As to the origin of these stupendous rocks, there can be but one explanation; namely, that they were originally contained as central nuclei in gneiss; which from a peculiar tendency to decay, mouldered into friable earth, and was removed by the torrents, leaving the present masses exposed upon the surface. Nor is this a mere speculation; for the fact is established by numerous masses of a similar nature, progressively undergoing the same changes; and so rapidly do they take place, that even human institutions are sufficient records of the sinking and decay of mountains. A most instructive and humiliating instance of the changes that are taking place in the physical, as well as in the moral world, is presented by the ruins of Chompawut,* the ancient capital of Kemaon.

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* Now called Kálí Kemaon.

"The catastrophe by which Herculaneum was destroyed, was but the excessive operation of causes, to the effects of which, certain countries were ever liable: such also is the destruction of a city by an earthquake. Visitations of this kind are, indeed, terrible to contemplate, but they are generally sudden, and of brief duration. Not so is the silent and slow destruction of a city, by the decay of the rock on which it is erected: here the horrors of desolation must necessarily be protracted, and in the case of a people who must have been more ready to ascribe the catastrophe to a slow and vengeful destiny, from which it were useless to attempt escape, rather than to a law of physics, that a better informed people would have understood, the effects must have indeed been awful. Yet such appears to have been the fate of Chompawut.

"This city was erected on gneiss at the northern side of Choura Pany, and was totally destroyed by the decomposition of the eminence on which it stood. A few vestiges only remain, owing to the accidental circumstance of their having been erected on the more durable beds of the rock; but in other respects, although built of granite, and probably intended to endure for ever, scarcely one stone remains on another."

Ruinous as these changes may be in the districts where they occur, yet the results are, in the highest degree, conducive to the best interests of mankind. The rains which devastate the rock bear its potash to the plains, where this substance exercises the most beneficial effects on vegetation; and when the vegetable has fulfilled its functions, the alkali is still available for innumerable uses to mankind. By its solvent power, it, in the first place, brings into the fluid state many vegetable and animal principles highly fitted for the nutrition of growing plants. With these juices it ascends and circulates through the vegetable fabric, and when this decays, on burning its stalks and leaves we obtain the potash from the ashes. Thus in the fertile district of Tirhut, the indigo plant receives its nourishment from a soil so enriched, and when the precious dye is extracted, the plant is valuable still from the large quantity of potash it contains.

I shall again return to the sources of potash; meanwhile we should learn the properties of its metallic base.

POTASSIUM. (P. 39, 15.)

Potassium was discovered in 1807, by Sir Humphrey Davy, who obtained it by decomposing potassa by the galvanic battery. The metal appeared in brilliant globules at the *negative* pole, and oxygen passed to the positive side. Other processes were subsequently devised, by which larger supplies of the metal were obtained. Thus by bringing fused potassa into contact with iron turnings heated to whiteness in a gun barrel, the iron attracts the oxygen, and potassium is distilled over, and may be collected in a receiver filled with naphtha.

The most economical and convenient method, however, is that invented by M. Brunner. A mixture of carbonate of potash and charcoal, prepared by calcining super-tartrate of potash, (see that head,) is placed in an iron bottle, furnished with a bent gun-barrel terminating in a naphtha receiver. The iron retort is heated to redness, and on increasing the temperature, in about half an hour potassium sublimes and is condensed in the receiver. From half a seer of the calcined cream of tartar, from six to eight drachms of the metal have been obtained.

Potassium is solid at the temperature of 60°, softens at 90°, and melts at 150°. It sublimes at a low red heat. In its solid state its appearance exactly resembles silver. Its specific gravity is only 0·865, being thus much lighter than water, on the surface of which it consequently swims, decomposing it so rapidly that the potassium takes fire and burns, while floating on the water, with a rich violet flame. So great is its attraction for oxygen, and so intense is the heat generated, that potassium inflames when brought in contact with *ice*.

By means of several analyses it has been ascertained that potassium combines in the proportion of 39.15 parts to the equivalent of the other simple bodies.

OXIDES OF POTASSIUM.

The OXIDES OF POTASSIUM are *two*, the protoxide and peroxide.

The *Protoxide*, (P. O.) or the potassa of familiar chemical language, is produced in its utmost state of purity by exposing potassium to the air or oxygen gas. In its pure state this oxide is white, caustic, extremely soluble in water, also soluble in alcohol fusing at a red heat. With 1 eq. of water it forms a *hydrate*, which retains its water, although heated to the most intense whiteness in a blast furnace.

This *hydrate* is formed in its pure state by decomposing water by potassium, evaporating to dryness, and heating the residuum to redness. It is soluble in half its weight of water, and also in alcohol, and extremely caustic, decomposing all animal and many vegetable structures.

Pure potassa, either solid or in solution, possesses alkaline properties to the most remarkable degree: it saturates all acids, and when combined with some of weak powers, such as the hydro-cyanic or carbonic, still shews alkaline characters. It decomposes nearly all saline compounds, uniting with the acid, and ejecting the base previously in combination.

The *Peroxide* (P. O_2) is formed by burning potassium in oxygen gas, or by conducting oxygen gas over potash at a red heat—or by decomposing nitrate of potash by heat in open vessels. It is an orange-coloured substance, and when dissolved in water is converted into the protoxide, and oxygen gas escapes.

TESTS OF POTASSIUM COMPOUNDS.

With tartaric acid, potassa forms a white crystalline compound difficultly soluble in water, the bi-tartrate of potash or cream of tartar. With perchloric acid it also forms a sparingly soluble salt. With chloride of platinum it causes a yellow precipitate; and a solution of carbazotic acid ("see Indigo,") throws down potassa in yellow crystals. Oxide of nickel, if fused with borax before the blow-pipe, forms a brown glass, which, if melted with a mineral containing potash, becomes *blue*. By these characters potassa is distinguished from every other substance.

The uses of potassa are extremely numerous in medicine and in the arts, but I shall not insert their description until I have completed the sketch of the other chemical compounds of the metal.

CHLORIDE OF POTASSIUM. (Ch. 35. 42. P. 39. 15.)

The *Chloride of Potassium* may be formed by burning potassium in chlorine, or decomposing muriatic acid gas by the metal, or by heating the chlorate of potassa until all its oxygen is expelled: or, lastly, by dissolving potassa in muriatic acid and evaporating to dryness. It is soluble in water, but not in alcohol, and is but of little use.

IODURET OF POTASSIUM. (Iod. 126. P. 39. 15.)

The *Ioduret of Potassium* is a very important medicinal substance: it is prepared by adding iodine to a hot solution of potash, until the solution does not affect turmeric test paper. By the decomposition of water, the iodate and hydriodate of potash are formed, and on evaporating to dryness, a mixed salt (iodate of potash and ioduret of potassium) remains.

By heating this to low redness in a covered platinum crucible, the iodate of potassa loses all its oxygen, so that the entire mass consists of ioduret of potassium. It is composed of 1 eq. of iodine, ... 126
I eq. of potassium, ... 39.15

Total, ... 165.15

This compound occurs in white, semi-transparent, cubic crystals; fuses readily, and sublimes at a low temperature. It is soluble in two-thirds its weight of water, also in alcohol. The solution dissolves iodine freely, forming in certain proportions mixtures of great value in medicine.

The ioduret of potassium sold in the shops is generally adulterated with carbonate of potash, from which it may be separated by strong alcohol. A ready test of the adulteration is a solution of the *acetate of lead*, which gives a fine yellow precipitate (ioduret of lead) with the pure, a white precipitate (carbonate of lead) with the adulterated salts. This adulteration was discovered and described about the same time by Mr. Pereira and myself, and I have frequently found it to amount to the almost incredible proportion of 60 per cent. The infamous fraud is perpetrated, moreover, by many drug establishments of high name; and in the practice of medicine it inevitably baffles all the skill of the physician, by frustrating his views in the administration of the remedy. In the Appendix to my "Translation of Lugol's work on the treatment of Scrofula," this adulteration and its consequences are minutely described.

SULPHURETS OF POTASSIUM.

The *Sulphurets of potassium* are very numerous. The proto-sulphuret is prepared by heating sulphate of potassa to redness with charcoal, or by exposing it at the same temperature to a current of hydrogen gas. In the former case carbonic acid, in the latter water, is formed, and proto-sulphuret of potassium remains. It is of a red colour, crystalline texture, attracts moisture from the air, is soluble in water and alcohol, and is decomposed by the mineral acids, sulphur being deposited and sulphuretted hydrogen set free.

The bi-sulphuret is of too remote a degree of interest to call for description. The ter-sulphuret is formed when carbonate of potassa is heated to low redness with half its weight of sulphur, the oxygen of three-fourths of the potassa converting part of the sulphur into sulphuric acid, and the remainder of the sulphur and potassium entering into direct combination. This compound is commonly called the *liver of sulphur*, and will be alluded to again in speaking of the medicinal preparations of potash.

A *quadro*-sulphuret and *quinto*-sulphuret of potassium have also been formed, the latter by fusing together equal weights of sulphur and carbonate of potash.

When these sulphurets of the metal dissolve in water, they may be considered to become hydro-sulphurets of its oxide, and in this state they evolve sulphuretted hydrogen gas when an acid is added. Their solutions are used as tests for various metals, and for withdrawing oxygen from atmospheric air, as explained in the section on that subject.

THE SALTS OF POTASH.

These are very numerous, and of the greatest importance when considered in regard to their uses in medicine, in warfare, and in the arts. I shall describe, in the first instance, those used in large manufacturing operations, describing the peculiarities of the medicinal compounds under a separate head.

CARBONATES OF POTASH—PEARLASH OR POTASHES OF COMMERCE. —KOHARA LAVANA, *Sanscrit;* JHA'R KA'NIMAK, جهاڑ کا نمک *Hindustáni.*

This salt is prepared in immense quantities by burning land vegetables, washing the ashes in water, evaporating the solution to dryness, and heating the resulting mass to redness in a furnace. The largest proportion of potashes is afforded by herbs, than by the leaves of trees and shrubs, and by woods the least. It is found also that plants of different descriptions give different quantities of the salt. In Russia the trees of the birch, beech, and poplar; in America the hickory and maple; in France vine stalks; in Ireland ferns and potatoe stalks; in India the indigo plant, plantain, or cocoanut leaves are respectively preferred to other vegetable substances natives of the same localities.

Pearlash is consumed chiefly in the manufactures of soap and glass. It is imported into England principally from the Baltic at 1*l.* 18*s.* 6*d.* per cwt. duty 6*s.* and from America at 1*l.* 16*s.* to 2*l.* 2*s.* duty free, and sells at from 2*l.* 10*s.* to 3*l.* the hundred weight, according to the quality of the article.

Entertaining a firm conviction that pearlash might be made a highly profitable export from this country,* I subjoin sufficiently minute directions for its manufacture on a large scale, by the Russian and American methods. I shall also give another plan still more suitable to some localities in India.

A deep trench is first cut in the ground, with the bottom and sides of brick, the plants and trees thrown in and slowly but completely burned. The ashes are then stored,

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* Although I have not altered this passage, I have now reason to doubt the correctness of this opinion. The price of potash has since fallen in England—freights have risen, and the insurance offices would, I find, demand a very high premium from vessels carrying this salt, on account of its corrosive nature and the great difficulty of preventing its escape during a long voyage. The expense of cooperage is another formidable difficulty.

and the longer they are kept the less difficult and expensive is the succeeding step, the washing, by which the salt is removed from the earthy impurities.

Each parcel of ashes is subjected to three washings with hot water. The first gives a strong ley—the second and third much weaker, but these are successively used with fresh ashes until the entire becomes of the specific gravity of 1.114, (Beaumé's hydrometer 15° at the temperature of 80°). For the evaporation as well as the heating the water, three fire-places are used, two supporting boilers for the evaporation, the third a cast-iron pot for the perfect drying of the salt. Close to these furnaces stand fifteen barrels in three rows for the washing. The flues of these fire-places pass under a boiler of large size for heating water, which is led by leaden pipes and cocks into the barrels. In each barrel is placed an inverted earthen pot about six inches deep, in order to keep the lower part of the vessel free;—above this is laid a layer of straw. This is covered by a cloth, and, lastly, the barrel is filled with the ashes. Hot water is gradually added, until the vessel will hold no more. It is allowed to rest for twelve hours, and then drawn of by an aperture below. This operation is repeated till the ashes are exhausted of their salt. The fluid removed is replaced in the boiler, and passed over fresh ashes till it attains the proper density. The evaporation is now performed, and, lastly, the dried mass is calcined in a reverberatory furnace. To roast 1200 seers of the salt will require 70 cubic feet of firewood of a solid dry kind. The furnace is so constructed that the flame from a large fire plays on the surface of the saline mass placed in the receiving chamber. The roasting requires several hours' work. The charge of the furnace first blackens, then flames, crackles and froths up. When it becomes white the operation is finished.

The potashes of commerce differ much in degree of purity, containing varying proportions of earthy carbonaceous matter, sulphate of potassa, and sulphuret and chloride of potassium.

As the value of the salt depends on the quantity of alkaline potash which it contains, the best test is by ascertaining the exact quantity of the salt under examination required to saturate a certain quantity of sulphuric acid of known strength.

This process is termed *alkalimetry*, and is thus performed. Into a tube sealed at one end, 9½ inches long, ¾ of an inch in diameter, and of uniform bore, pour 1,000 grains of water; mark the level of its surface with a file, and divide the space occupied by the water into 100 equal parts. Opposite to the numbers 23½, 49, 54½, and 65, draw lines. At the first write S. for soda; at the second P. for potassa; at the third C. S. carbonate of soda; and at the last C. P. for carbonate of potassa. A standard acid, specific gravity 1,127, is next to be prepared by mixing one measure of concentrated sulphuric acid with four measures of distilled water. This acid is of such strength, that if poured into the tube till it reaches any of the marks, we have the exact quantity of acid necessary for neutralizing 100 grs. of the alkali expressed by the letters.

Consequently, if, when the acid reaches C. P., we then add distilled water to the 100 mark, it is evident that each division of the tube corresponds to one grain of the alkali. All that is necessary then is to dissolve 100 grains of the specimen under trial in distilled water, and gradually add the acid from the tube until the alkali is neutralized, which is ascertained by a slip of paper dyed yellow by turmeric, the colour of which is rendered red by the alkali, but is not affected by neutral salts. If then 30, 40, or any other number of parts of the acid in the tube be consumed, the quantity represents the alkali contained in 100 grs. of the specimen examined.

If the salt contains a soluble sulphuret, especially sulphuret of calcium, (hydro-sulphuret of lime) which most specimens of English barilla (soda salt) abound in, the above process will give a fallacious result. A part of the sulphuric acid will be expended on saturating the lime, and thus the salt appears more alkaline than it really is. Alkalies containing soluble sulphurets blacken solutions of lead. All specimens must therefore be tested with a few drops of acetate of lead, and if the mixture be blackened, it will be necessary to have recourse to some simple mode of removing the sulphuret.

As all soluble sulphurets rapidly attract oxygen from the air and pass into sulphates, it suffices to pour the solution in very shallow layers on glazed plates for a few hours. Sulphates of lime, iron, soda and potash are formed by the sulphur and its associated metal attracting oxygen from the air. The solution now no longer blackens the salts of lead, and will give precise results with the alkalimeter.

It is always expedient to test the standard acid by actual experiment with 100 grains of dried carbonate of soda and the same quantity of dried carbonate of potash. According to the indications given, the alkalimeter may be corrected or the acid may be strengthened or weakened as required.

In India in some localities a pure carbonate of potash may be very cheaply, quickly, and easily manufactured by the following process, which I can strongly recommend.

Melt saltpetre in an iron pot, and gradually add powdered charcoal until it ceases to take fire. The nitre is decomposed and carbonate of potash formed,—rendered impure, it is true by the presence of iron, but by washing with water, filtering through cloth and straw, the greater part of the impurities are effectually removed.

A still easier, and perhaps more productive method is to mix powdered saltpetre with twice its weight of powdered charcoal, and project the mixture by small quantities into an earthen vessel, containing a fragment of red hot charcoal—treat the residuary mass as above directed.

In France and the German wine districts, a very pure carbonate of potash is prepared by burning the dried lees of wine, which consists chiefly of bi-tartrate of potash. The tartaric acid is decomposed and carbonate of potash remains. For chemical purposes, the purest carbonate of potash is made by this process, the best white cream of tartar being employed instead of wine lees.

The carbonate of potash when pure is extremely deliquescent. By transmitting a current of carbonic acid gas through a solution of it, a *Bi-carbonate* is formed, which is permanent in the air, and crystallizes in eight-sided prisms. It requires four times its weight of cold water for its solution, and at a boiling temperature loses 1 eq. of its acid.

The uses of carbonate of potash are alluded to under the heads of carbonate of Soda and Silica, in treating of soap and glass. I now proceed to one of the most important of Indian productions,—Saltpetre, or

THE NITRATE OF POTASH.

In treating of this substance, I consider that I shall best consult the wishes and interests of the Indian student and mercantile reader, by presenting them with an account of the production and purification of nitre in other countries, and in scientific hands. Mr. Stevenson's Essay on the saltpetre manufacture in Bengal is already, I presume, in extensive circulation, and supersedes the necessity of my offering many details relative to the Indian system.

Origin of Nitre. The nitrates of potash, soda, lime, and magnesia are found as natural productions in various localities—the nitrate of lime being that formed in the greatest abundance—that of soda being the next, and of potash the least plentiful.

The sources of the lime, magnesia, potash, or soda, are intelligible enough, these substances being always found in the soil where the nitrate is produced. The origin of the acid is less evident, and has occasioned much difference of opinion among scientific men.

All the older chemists believed that the oxygen was furnished by the air, the nitrogen by the putrefaction of animal matters in the soil; but in opposition to this view stands the conclusive fact, established by the researches of modern analysts, that in 100 lbs. of saltpetre there is more nitrogen than in 75 lbs.

of dry, or 400 lbs. of moist animal matter. This disproportion is so great that the fact at once decides the impossibility of animal matters being the sole source, although sometimes concerned, in the production of the nitric acid. A beautiful experiment performed for other objects by the great Cavendish, affords us a more correct notion of the process. He enclosed a portion of atmospheric air in a tube containing some caustic potash, and subjected the air to the action of a series of electric sparks. Nitric acid was produced and saltpetre formed. All the circumstances therefore essential to nitrification are, the presence of powerful alkaline bases, of atmospheric air, and the passage of the electric fluid. But such is the exact condition of the natural nitre districts in hot climates. The soil contains lime and occasionally potash, and violent thunder-storms keep the air in frequent electric excitement. Nor is it less probable that the galvanic currents, now proved to circulate at the surface of the globe in determinate directions, indirectly though powerfully promote the formation. It is a curious fact, moreover, that the carbonates of the earths and alkalies are nitrified much more quickly than these bases alone. A certain degree of moisture and a moderately warm temperature are also favourable to the process.

Notwithstanding the preceding facts, it is no less certain that the presence of decomposing animal matter promotes and expedites the formation of nitrates. M. Dumas, I believe, suggests the true explanation of what takes place. He considers that the chief use of the animal matter is, by its decomposition, to furnish carbonate of *ammonia*, which acts as a substitute for other alkaline bases, the presence of which is indispensable to the generation of the nitric acid.

The production of the nitrates may be considered to be of two kinds—the *natural* and *artificial.*

In South America the nitrate of *soda* is found in great quantities in some districts. In the caves of Ceylon, in some districts of Tirhut, in certain localities in Egypt, in Spain, in the caves of Roche-Guyon and Mousseau near Paris, and in the sandstone hills of Kentucky, nitrate of *potash* is produced. But the nitrate of lime is by far the most abundant of all, especially in the great manufacturing districts of India, where, as we shall subsequently find, it is converted by means of carbonate of potash into nitrate of potash.

The *artificial* nitre beds are of various kinds. In Sweden the operation is carried on under wooden sheds with planked floors. On the floor is placed a mixture of common earth, chalky sand, or marl, and wood-ashes. The mixture is sprinkled from time to time with the urine of cattle. In summer the mass is stirred up once each week, in winter once every fortnight. The heap of earth is generally from 2½ to 3 feet deep, and the shed is provided with venetians to admit the air, but exclude the light. The produce is estimated at 4 ounces of nitre to the cubic foot of earth, being about 8,000 cubic feet of earth, which must be washed to afford 1,000 seers of saltpetre. The production of the nitre requires about three years from the commencement of the process, and one-third of the mass of soil is annually subjected to washing.

In Switzerland a nearly similar plan is pursued, the manufacturers preferring a northern aspect for the sheds. The French prepare the soil by strewing earth in sheepfolds, and keeping it constantly moistened by a mixture of water and manure. In Prussia a much more economical and judicious system has been followed. The process consists of two periods, the first being the *preparation* of the nitre soil by any of the plans previously alluded to. With the earth thus procured, walls are constructed 6 or 7 feet high, 3 or 4 feet thick, and parellel to each other. One side of the wall is perpendicular, one sloping so as to conduct the rain towards reservoirs, where it is collected to be used for the sprinkling of the soil. In building the walls, bushes are introduced into the earth for its support. The sloping face of the wall should be disposed towards the prevailing winds. The nitrate forms, filters through the wall, and collects on the perpendicular surface which is scraped away according as the salt is formed, the scraping mixed with wood-ashes, washed, evaporated and crystallized. The earth remaining after the washing is again replaced on the original slope, it being found that earth which has once yielded nitre generates it more readily again.

EXTRACTION OF THE SALTPETRE.

M. Dumas in his admirable book divides this processes into four stages:—

1. A washing to separate the nitrates of potash, lime, or magnesia from the earthy and insoluble matter.
2. The addition of a salt of potash to the washings, in order to change the nitrates of lime and magnesia into nitrate of potash.
3. Evaporation and crystallization.
4. Purification and separation from the salts which are mixed with the first crystals.

Washing. To this head I would especially request the manufacturer's attention, since the subject is not minutely dwelt on in Mr. Stevenson's pamphlet; while its careful consideration will effect a most important saving of labour, fuel, and time.

The system of washing described by Dumas, is that published by the French Commissioners in 1820. Its advantages are so important, that I give it in close detail; and I do so the more willingly, as it may serve as a model for the extraction of saline matter of every other kind.

If we place as much saltpetre earth as contains 8 seers of saltpetre in a vat provided with a cock, and if 60 pints of water be added, and if in 12 hours we open the cock, one-half the fluid will flow out, one-half be retained in the interstices of the mass. Now all the saltpetre has been dissolved, one-half is consequently retained in the vat. If we now add 30 pints of fresh water, and in three hours open the cock, we draw off 30 pints containing one-half the saltpetre remaining from the first washing, or one-fourth of the original quantity: a third washing extracts one-eighth; a fourth one-sixteenth; and so on. Thus in four washings we have—

	Water employed.	*Liquor obtained.*
1st Washing,..	60 pints,..	30 or 4 seers nitre.
2nd ditto, ...	30 ditto, ...	30 ,, 2 ditto.
3rd ditto,..	30 ditto,..	30 ,, 1 ditto.
4th ditto, ...	30 ditto, ...	30 ,, ½ ditto.

The loss will hence be one-sixteenth of the saltpetre. Now the same quantity of saltpetre could not be removed by a single washing, such as that advised by most writers, unless 3¾ times the entire quantity of water were employed. Thus the economy of fuel resulting from this method is as 35 to 10, compared with the system usually followed.

This saving may be still further extended by taking the 60 pints of liquid extracted in the first and second washings, and pouring these on fresh earth, containing 8 seers of nitre. In twelve hours 30 pints may be drawn off, containing 7 seers of saltpetre. Thus the manufacturer has only to evaporate 30 pints of water for the extraction of 7 seers, instead of 200 for 7½ seers. The consumption of fuel is consequently diminished by three-fourths. I have made extensive inquiries among gentlemen engaged in the saltpetre business in Behar and Tirhut, as to their mode of washing. As far as I have heard, the system I now describe has never yet been attempted in India, even in the late Government factories. My friend Mr. Hurry informs me that since the above process was pointed out in the first edition, it has been adopted in his factories with perfect success.

Starting with these preliminary ideas, I follow M. Dumas in his sketch of the manufacture itself.

For the washing of the earth, the French manufacturers use barrels, each provided with a false bottom and cock or spigot, the false bottom being covered with a layer of straw and broken tiles. Thirty-six such barrels are used in a factory yielding from 12 to 15,000 seers of saltpetre per annum. They are disposed in three rows, and filled with earth pressed gently in and rather concave at the top. Water is poured to an inch above the surface of the entire.

In the usual course of manufacture they commence by watering only one of the rows of barrels, the quantity of water being half the bulk of the earth. This is allowed to remain ten hours, and is then left to drain. The water is then replaced, and this is repeated a third and fourth time. The first washing is in each instance collected separately, and the others successively used with the barrels of the second row. From these again the second and third washings are used with the third row of barrels; and in this order, according to the principles above described, the operation proceeds.

The manufacturer will readily understand that wooden tanks or vats of larger dimensions may, in some instances, be advantageously substituted for the barrels above described. When properly conducted, the washings ought, when mixed, to yield a liquid of the density of 1,300 which is easily ascertained by the use of the specific gravity bottle or displacement ball described in the Appendix.

The liquid thus prepared contains but little saltpetre, but a considerable proportion of nitrate of lime, with sulphate and muriate of soda. The next step is to convert the nitrates of lime and magnesia into the nitrate of potash. For this purpose some cheap kind of carbonate of potash is employed; such as the ashes of the indigo plant, the sulphate of potash resulting from the manufacture of sulphuric acid, the chloride of potassium, &c. &c. As ashes can alone be employed in India for very many years to come, I will confine myself to a description of the mode in which they are used in Europe.

The ashes are first packed in barrels disposed nearly in the same manner as the washing vats. The washings are then poured over the ashes in the proportion of 15 measures of liquid to one of ashes. By this mixture the carbonate of potash of the acid decomposes the nitrate of lime and magnesia, insoluble carbonates of these earths remaining in the vat, and a solution of nitrate of potash passing through; still, however, retaining the muriate and sulphate of soda resulting from the original soil, and a considerable proportion of animal and vegetable matter.

Evaporation. The subsequent remarks apply almost as appositely to the boiling down of the *Doah* or crude saltpetre of Tirhut as to the evaporation of the liquid obtained by the preceding steps. These liquids, as well as the solution of the *Doah*, contain carbonate of lime and magnesia dissolved by an excess of carbonic acid derived from the carbonate of potash. They contain also animal and vegetable matter coagulable by heat, together with sulphate of soda and common salt in large proportion.

Copper or sheet-iron boilers may be employed. Regarding these and the mode of heating the crystallizing pans, Mr. Stevenson's Essay may be advantageously consulted.

When the liquid commences to boil, there first forms a white scum of animal and vegetable matter, containing a considerable quantity of sulphate of soda, which salt has the curious property of becoming insoluble to a certain extent when the temperature of its solution *increases*,—a remarkable exception to the law of increase of solubility by addition of heat. The scum is to be removed and added to the earth preparing for another season.

In the next place, a dense muddy precipitate falls, composed chiefly of carbonate of lime and magnesia. In France great care is taken to remove this mud by means of shallow pans placed before the heating at the bottom of the boiler. The object of this measure is to prevent the mud accumulating and hardening at the bottom of the boiler, thereby diminishing its conducting power for heat, squandering fuel, and often leading to the burning and destruction of the boiler itself.

When the evaporation has attained a certain point, the common salt, being nearly of equal solubility in hot and cold water, begins to crystallize, and collects at the bottom of the boiler, from which it is ladled out and stored in bambú baskets. At this period of the process it is strongly recommended to diminish the fire,—a step which, it is true, slightly prolongs the operation, but enables the saltpetre to crystallize with greater solidity and in more regular forms.

When the liquid ceases to deposit the common salt, or when a drop solidifies if placed on a cool surface, it is drawn off into crystallizing vats, containing peeled bushes as mechanical supports for the crystals. Care is taken that the surface of the liquid is kept free from dust or agitation by currents of air. Before drawing off the liquid from the boiler, Mr. Stevenson recommends the addition of a few seers of cold water,—a plan which he deems of much importance. He states that the crystals combine with this water; but in this he is not quite correct, for nitre is a salt which contains no water of crystallization. I believe the only use of the cold water is to reduce the temperature of the liquid more speedily than can be effected by the withdrawal of the fire. However this be, the direction is worth following, as emanating from an experienced and very observant manufacturer.

Refining. The saltpetre obtained by the preceding or similar steps is termed *kalmi* in the Indian bazars, and contains from 6 to 25 per cent. of sulphate and muriate of soda. To remove these impurities, Mr. Stevenson recommends that the article be placed in shallow bambú baskets, and washed with a small quantity of cold water. This, he states, quickly washes away the extraneous salts, removing but little of the nitre. He adds, that by this plan the nitre is brought to 98 per cent. of purity, with a loss of but 6 per cent. of saltpetre; whereas by a second crystallization, he considers the loss to be 25 per cent. and the quality of the salt not at all superior.

I am unwilling to obtrude an opinion on a subject on which Mr. Stevenson possesses practical knowledge, to which I cannot lay claim. The results of his plan are, moreover, so described by him, as to leave no doubt of its great success under *his* management. But I have heard the method strongly objected to by experienced manufacturers, chiefly on account of its alleged wastefulness. They say, that unless the proprietor of the factory be constantly present during the washing, the loss of saltpetre is extremely great, and that, consequently, the expense and trouble of superintendence counterbalance the benefit. Should this objection be well founded, I would suggest the following simple method, which will effectually remove all extraneous salts and leave the nitre untouched.

A saturated solution of *good* saltpetre in cold water should be prepared, and its power of dissolving common salt ascertained by direct experiment, with a pint of the solution on weighed grains of salt. Let this solution be used instead of water and collected again, and its use continued until its power of dissolving salt ceases by its saturation, which can be very easily found by experiment. Let the solution be now evaporated in a small boiler till it deposits the common salt, and it will again be found fit for use as before. A few maunds of fine saltpetre thus kept in employment will soon be found a very profitable investment.*

It is useless to describe in detail the steps of the second crystallization to which saltpetre is subjected, when it is necessary to bring it to a state of absolute purity.

ASSAY—SIMPLE METHOD OF THE FRENCH.

The impurities in commercial saltpetre are termed, in mercantile language, the "refraction,"—an utterly inapplicable word, but conventionally well understood.

The usual impurities are water, sulphate of soda, and muriate of soda. The amount of the first is ascertained by weighing 100 grains of the saltpetre, and drying it on a soup-plate heated over a pipkin of boiling water. The loss indicates the exact quantity of moisture.

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* Mr. Hurry's overseer has tried this plan extensively, and reports it to be perfectly successful.

The *sulphate of soda* is detected and its quantity appreciated by adding nitrate of baryta and a little nitric acid. An insoluble sulphate of baryta subsides, is collected, dried and weighed.—118 parts of this compound indicate 63 of sulphate of soda; thus—

Sulphuric acid	40	Oxide of barium	78
Oxide of sodium	31	Sulphuric acid	40
Sulphate of soda	71	=to sulphate of baryta,	118

The *muriates* are detected by adding gradually a solution of nitrate of silver to a solution of 100 grains of the saltpetre in half a pint of distilled water. A white precipitate of the chloride of silver is formed, which should be collected on a filter dried at a low temperature and weighed. $143\frac{7}{10}$ grains are equivalent to $58\frac{7}{10}$ grains of common salt; thus—

Chlorine,	35.72	exchange elements with	Silver,	108
Sodium,	23.3		Chlorine,	35.72
Common salt	58.75	= to Chloride of silver,		143.72

It must be obvious, however, that these experiments only indicate the quantity of chlorine and sulphuric acid: they do not identify the base, which, it is equally clear, may be soda, potash, lime, or magnesia, the equivalent numbers of which are, respectively, potash 47—soda 31—lime 28—magnesia 20. It is true that in India the sulphate of soda is the impurity generally found, and even this in rather minute quantities; but I have very frequently met with specimens containing muriate of potash, as well as muriate of soda. In such cases, the usual analysis gives very deceptive results. While $143\frac{7}{10}$ chloride of silver indicate $58\frac{7}{10}$ common salt, they are equivalent to 74 of chloride of potassium. Such nitre is much more difficult of purification, attracts moisture very quickly, and is objected to by the gunpowder manufacturers. It would be useless were I to give minute directions for the chemical detection of this impurity. The process is too difficult and elaborate to be performed by any but a skilful chemist. It depends chiefly on the application of the platinum test described in the section on that metal. The whole of the potash base can be thus estimated.

The subjoined directions, however, can be accurately followed by any careful person, however destitute of scientific acquirements, and the plan possesses the advantage of economizing expensive tests, which are often very difficult to procure—and of indicating exactly the quantity of pure saltpetre, without having recourse to the calculation of equivalent numbers.

A pint of saturated solution of *pure* nitre in distilled water is poured on 1000 grains of the salt to be examined, previously dried and coarsely powdered. The mixture is stirred with a glass rod for a quarter of an hour, then allowed to settle and decanted. Half a pint of fresh nitre solution is again added, and in fifteen minutes the whole is filtered. When all the liquid has drained through, the filter is carefully compressed between folds of common unsized paper. When sufficiently dry to be removed from the paper, it is dried on a plate over hot water or sand. The weight is then accurately taken; the solution of saltpetre employed removes no nitre from the specimen, but washes out all the extraneous salts, and deposits two parts of saltpetre for every 100 of common or other salt taken up. The loss of weight consequently indicates the impurities—and from the actual weight two per cent. are to be subtracted. The remainder is the exact amount of pure saltpetre in the specimen examined.

Properties of pure Nitre.

The nitrate of potassa crystallizes in six-sided prisms, is soluble in seven parts of water at 60° and in less than its own weight of boiling water. It is insoluble in alcohol. It has a sharp, slightly bitter, cooling taste. When exposed to heat it fuses, and at first oxygen escapes and nitrate of potash is generated. As the heat increases, the nitrous acid is changed into nitric oxide and oxygen, the latter escaping, the former remaining in combination with potash. Elevating the temperature still more, the binoxide is resolved into nitrous oxide and oxygen, the oxide remaining with the alkali. Lastly, nitrogen gas is disengaged and peroxide of potassium remains. But if the heat be irregularly urged, the gases enumerated are given off in an uncertain order, and hence the nitre may simultaneously yield oxygen, nitrogen, and nitrous oxide.

The chief use of nitre is in the preparation of gunpowder and fireworks. Mixed in small proportions with common salt, it is found to aid in the preservation of animal matter, to which in many cases it imparts a fine red colour.

In hot climates it is mixed with sulphate of soda, and the solution employed as a cooling mixture.

In India, nitre may be economically used for the manufacture of potash, as I have already explained. In various chemical processes, such as the manufacture of sulphuric acid, the purification of silver, in glass-making, and numerous other arts, the employment of nitrate of potash is very extensive.

SULPHATE OF POTASSA.

The *sulphate of potash* is obtained in large quantities from the residuum of the nitre and sulphur used in making sulphuric acid. In the preparation of nitric acid there also remains a large proportion of this salt. Its uses are but of little importance, except in countries where nitre is extensively manufactured, as it answers the purpose of wood-ashes, by converting the nitrate of lime into nitrate of potash.

BI-TARTRATE OF POTASSA, OR CREAM OF TARTAR.

The tartaric acid exists in several fruits, usually in combination with lime or potash. It is very sour, soluble in six times its weight of water at 80°; is also soluble in alcohol, crystallizes in rhombic prisms, and is distinguished by forming two salts with potassa: one, the neutral tartrate which is extremely soluble in water—the second, the bi-tartrate, contains 2 eq. of acid, and requires sixty times its weight of water at 60°, and fourteen times its weight at 212° to effect its solution.

The tartaric acid forms some very important salts, which will be noticed in describing their respective bases.

The bi-tartrate of potash exists in abundance in the juice of apples, grapes, and tamarinds; and is deposited during the fermentation of wine on the inside of the casks. The coloured crust thus formed is purified by being boiled in water mixed with the whites of eggs, and the crystals deposited on cooling are called the *cream of tartar*. When 189 parts of this substance are boiled in water with fifty of carbonate of lime, an insoluble tartrate of lime subsides, and neutral tartrate of potash remains in solution. By adding to this a solution of muriate of lime,—that, for instance, remaining after the preparation of ammonia, more tartrate of lime is procured. By heating the whole of the tartrate of lime procured with 80 parts by weight of sulphuric acid, diluted with twice its bulk of water, the tartaric acid is separated from the lime, and sulphate of that base subsides.

There being no wine manufacture in India, we made every attempt, but ineffectually, to obtain this substance from the juice of the wild grape, and even of the cultivated kind; but we have succeeded perfectly in obtaining it economically from a more available source, the leaves of the tamarind tree, by the following process:—

Tamarind leaves (rubbed to coarse powder, 1 lb. dried before the sun or in the stove,) divide into two portions and boil each separately in porcelain vessels in a quart of water, stirring constantly for twenty minutes, strain while hot and press. To the hot liquor of one add solution of carbonate of potash to neutralization, strain if necessary, now mix the contents of both vessels and boil for ten minutes or a quarter of an hour, with a little moist white clay free from lime. Strain while hot, and set aside for crystallization.

The proportions above indicated may be observed on any scale. The product will, by proper management, amount to half an ounce of pure cream of tartar for every pound of the leaves.

When cream of tartar is exposed to a red heat, its acid is decomposed and pure carbonate of potash and charcoal remain, which may be separated by washing and filtration. Burned with half its weight of nitre, a similar compound, containing less carbon, is formed, which is much used in metal-working, and is called the *black* flux. With an equal weight of nitre or pure carbonate of potash, the white flux is procured.

MEDICINAL PREPARATIONS OF POTASH.

Solution of potash (aqua potassæ) is thus prepared. Take of pearlashes, fresh burnt quick-lime, of each 2 parts, water 13 parts; sprinkle one part of the water on the lime placed in an earthen dish, and immediately add the pearlashes and water; put the mixture into a stoppered bottle and keep it for three days, agitating it frequently. Then decant off the liquor and preserve it in green glass bottles.

In this process the lime takes the carbonic acid from the carbonate of potash, and the alkali is dissolved by the water. The solution should be of the specific gravity of 1080°, and it should not effervesce with acids.

Caustic potash (potassa caustica) is made by evaporating the preceding solution in a very clean silver or iron vessel until all the water is expelled and the alkali fuses. In this state it is to be poured on a silver or iron plate, and cut in pieces while still soft. Glass vessels or earthen vessels cannot be used, as they are corroded by the alkali.

Potash with lime (potassa cum calce) is made by evaporating the solution of caustic potash to one-fourth, then adding as much fresh burnt lime as suffices to form a thick paste, which is to be kept in close phials.

Pure Carbonate of potash is prepared for medical purposes by calcining cream of tartar in a crucible for two hours, boiling the residue in twice its weight of water, pouring off the liquor, and repeating this three times. The filtered liquors are mixed and evaporated in a silver basin, if this can be procured; if not, an iron one should be employed. The salt is finally heated to dull redness.*

The *Bi-Sulphate* of potash is obtained in the process for preparing nitric acid, described at page 48. The residual salt is dissolved in an equal weight of boiling water, which on cooling deposits the salt required. It is acid to the taste, and effervesces with alkaline carbonates. It is correctly described by the late Dr. Duncan as a valuable medicine, as it enables us to give sulphuric acid in combination with an aperient salt, and is less disagreeable than the neutral sulphate. It answers also, as Dr. Barker has pointed out, for making a cheap effervescing salt. Equal weights (one drachm) of bisulphate of potash and of carbonate of soda may be separately dissolved in two ounces of water, then mixed and taken while in a state of effervescence.

Acetate of potash is made by saturating carbonate of potash with distilled vinegar, and evaporating to dryness. The salt is to be fused by cautiously increasing the heat, then dissolved in water and evaporated a second time until it concretes in a crystalline mass. Twenty-one pints of distilled vinegar, sp. gr. 1,007, are required to saturate 18 ounces of carbonate of potash.

The *Acetate of potash* has a sharp pungent taste; is soluble in its own weight of water, and also in alcohol. It consists of 1 eq. acetic acid, 1 eq. potassa, and 2 eq. of water. It is a medicine of great utility, proves cathartic in doses of two drachms, and powerfully diuretic when given in doses of half a drachm, repeated occasionally.

Tartrate of potash is a mild aperient salt when given in doses

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* The saltpetre process previously described should be followed in India in preference to this.

of two or three drachms: it is prepared by dissolving 5 parts of carbonate of potash and 14 of cream of tartar, in 45 parts of boiling water. The solution is evaporated to crystallization.

The *Hydriodate of potash* has been already described under the head of *Ioduret of Potassium.*

The *Sulphuret of potash*, or liver of sulphur (ter-sulphuret of potassium), is best prepared by mixing two parts of carbonate of potash with one of powdered roll sulphur in a glass flask, and fusing the mixture by a gentle heat. The product is of a fine yellow colour, soluble in water and deliquescent in the air. Its solution is decomposed by acids, sulphuretted hydrogen being expelled.

The chief medicinal application of this substance is in the preparation of sulphuretted baths. Formerly it was much employed as an antidote to some metallic poisons, but its virtues seem to have been somewhat overrated.

SECTION II.

SODIUM AND ITS COMPOUNDS.

Sodium is the metallic base of the well-known alkali *soda*, and is obtained by processes exactly similar to those described under the preceding head. It is a white silver-like metal, quite soft at 90°, liquid at 200°, and volatilized by a red heat. Its specific gravity is 0.972. Like potassium it absorbs oxygen with great avidity, and decomposes water, but does not take fire on its surface. According to numerous analyses, the combining equivalent of this metal may be considered to be 23.

The compounds of sodium existing naturally are very numerous, and of the highest interest and value to mankind. With oxygen it forms the alkali *soda*, the chief ingredient in soap and glass, and in many other indispensable articles of daily use. With chlorine it forms sea-salt; oxydized and united with carbonic or sulphuric acid, it also occurs in great quantities as a natural formation.

OXIDES OF SODIUM.

The protoxide, commonly called *soda*, is formed when sodium is oxydized in air or water. It resembles potassa very strongly, and with water forms a hydrate composed of soda 31=eq., water 9=eq. which possesses the closest analogy to the hydrate of potassa, and is prepared exactly in the same manner. From potassa, however, soda is easily distinguished by the properties of the salts these bases respectively form with sulphuric and tartaric acids. The sulphate of soda becomes opaque and covered with a white powder on exposure to the air, and is fused by a very gentle heat. The sulphate of potash undergoes no change by the action of the air, and requires a red heat for its fusion. The bi-tartrate of potash dissolves with great difficulty; the bi-tartrate of soda is extremely soluble in water.

The *Peroxide of sodium* is formed when sodium is heated to redness in oxygen gas. It does not possess alkaline properties, and is converted into soda and oxygen by water.

CHLORIDE OF SODIUM, OR SEA-SALT.

The natural sources of this salt are extremely numerous. Ten thousand parts of sea-water contain 220 of chloride of sodium, 33 of sulphate of soda, 42 of muriate of magnesia and 7 of muriate of lime. The water of the Dead Sea contains, however, a much larger proportion both of common salt and muriate of magnesia.

Chloride of sodium exists also as a mineral called *rock-salt* in many countries, especially in Poland, and Cheshire in England. Lakes of salt-water are, moreover, common in many countries, of which the Sambre lake in the Joudpur territory affords an example.

The chloride of sodium fuses at a red heat; is insoluble in alcohol. It requires twice and a half its weight of water at 60° for its solution, *and its solubility is not increased by heat.* On this property depends the separation of this salt from the deleterious compounds of lime and magnesia with which it is associated in sea-water, which are much more soluble than the chloride of sodium in cold water, and their degree of solubility greatly increased by heat. Hence, on boiling down sea-water, the common salt is deposited as soon as the solution is concentrated, and the muriates of lime and magnesia remain dissolved, and may be separated by straining and other well-known processes. The rejected liquor is called *Bittern,* and is used in the preparation of sulphate of magnesia, bromine, muriate of ammonia, and other products.

The usual varieties of salt, even of the best kind, contain small quantities of sulphates of magnesia and lime. The mixture, however, sold as salt in the Bengal bazars, contains almost all the ingredients of sea-water, with the addition of sand and mud. It can only be the all-preservative effect of habit which enables the poorer classes to use this compound with impunity.

Chloride of sodium when pure, crystallizes in four-sided pyramids composed of sodium 23, chlorine 35-72. The crystals are not combined chemically with water, but often contain it mechanically enclosed in their interstices, and owing to its presence, they decrepitate when heated.

The ioduret, sulphurets, and cyanuret of sodium are so similar to the same compounds of potassium, that I need not describe them in detail.

CHLORIDE OF THE OXIDE OF SODIUM.

This compound is well known in Europe under the name of Labarraque's Disinfecting Soda Liquid. It is prepared without difficulty by saturating a solution of carbonate of soda with chlorine gas. It is necessary to be exact in the proportions used. Mr. Faraday directs 2,800 grs. of carbonate of soda to be dissolved in 1¼ pints of water, and through the solution to be passed the chlorine evolved from 967 grs. sea-salt, 750 grs. peroxide of manganese, and 967 grs. of sulphuric acid, diluted with 750 grs. of water. The chlorine is first passed through water in the first bottle of a Woolfe's apparatus. In the second bottle is placed the soda solution, which absorbs the chlorine without any evolution of carbonic acid.

The resulting liquid is of a pale yellow colour, has but a slight smell of chlorine, and does not give out that gas when boiled. It possesses strong bleaching properties, and when evaporated cautiously yields crystals, which when re-dissolved bleach almost as powerfully as the liquid itself.

It is decomposed by carbonic acid, chlorine being evolved. Hence when exposed to the air, especially where loaded with putrid vapours, the carbonic acid sets the chlorine free, which reacts on and destroys the offensive compounds.

The exact composition of the liquid obtained by the above process has not been ascertained. Dr. Turner deems it likely that the solution contains chloride and bi-carbonate of soda. Balard regards it as a compound of hypo-chlorous acid and soda. From the most recent experiments, especially those by Mr. Millon, it seems a compound of calcium, oxygen and chlorine, analogous to the metallic peroxides, an equivalent of chlorine being substituted for one of oxygen; he regards it also as a hydrate, with one atom of water.

SALTS OF SODA.

Of these the most important are the nitrate, sulphate, and carbonates.

The *nitrate of soda* (cubic nitre) strongly resembles the nitrate of potash. It has been found native in some parts of India, but its chief source is in Peru. When mixed with charcoal and sulphur, it burns so much more slowly than nitrate of potash, that it cannot be used for the manufacture of gunpowder, but it is employed with great advantage in the preparation of the sulphuric and nitric acids.

Sulphate of soda. This valuable salt is found in great quantities at the surface of the soil in many parts of India, especially in the neighbourhood of Purneah, in the Gangetic portion of the Oude territory near Cawnpore, and generally in all the ravines of grey kankar through the Doab. The salt is called by the natives *karí matí.* كري متي It occurs in a greyish mass, and is associated with muriate of soda, alumina, sand and lime, in such proportions that the washings yield 50 per cent. of pure sulphate of soda.

To obtain the pure salt on a large scale, the system of washing, boiling, removal of the common salt, and crystallization described under the head of nitre should be adopted. Even by a less economical procedure, the sulphate of soda is obtained and sold at 3 rs. 8 as. the maund.

Artificially, sulphate of soda is made in large quantities in Europe by decomposing sea-salt by sulphuric acid. The resulting sulphate is again converted into carbonate of soda by a process I will presently describe, and is consumed extensively by the manufacturers of soap and glass.

Sulphate of soda is composed of single equivalents of its acid and base. Its crystals are four or six sided prisms. They effloresce or become whitish when exposed to the air. They are insoluble in alcohol, and their solubility in water is curiously influenced by the degree of heat applied. Thus at 32° F.

100 parts of water dissolve 12 parts of the salt, at 64° the same quantity of water takes up 48; 100 parts are dissolved at 77°, 270 at 89°, and 322 at 91°. On increasing the heat beyond this point, a portion of the salt is deposited, its solubility thus decreasing as the temperature becomes higher.

PHOSPHATES OF SODA.

By adding carbonate of soda to the acid bi-phosphate of lime (page 116) phosphate of lime is precipitated, and phosphate of soda remains in solution. Evaporated, it crystallizes in rhombic prisms. Its solution is alkaline to test-paper; the crystals effloresce on exposure to the air, and are soluble in four times their weight of cold and twice of hot water.

The solution gives a *yellow* precipitate with nitrate of silver. Heated to redness, the crystals become the pyro-phosphate of soda, and then precipitate the salts of silver *white*.

This salt is composed of 2 eq. soda, 1 eq. phosphoric acid, and 1 eq. of water. Other compounds of phosphoric acid and soda have been described, but their study is of little importance.

CARBONATES OF SODA.

There are three compounds of carbonic acid and soda, containing respectively 1, 1½ and 2 eq. of carbonic acid, and named the carbonate, sesqui-carbonate, and bi-carbonate of soda.

The carbonate of soda is an article of high importance in a commercial point of view. Its natural sources are very numerous, and there are also many artificial processes by which it can be prepared. The chief uses of the salt are for the glass and soap manufactures.

In many parts of India the carbonate of soda is found in great quantities at the surface of the soil. In the neighbourhood of Monghyr, in the kankar ravines of the Doab, in many districts of the Mysore and Travancore territories, this valuable salt exists in inexhaustible abundance. The soil thus impregnated is called the *sáji mati* ساجي مثي It yields by simple washing an average of 50 per cent. of carbonate, with from 10 to 15 per cent. of sulphate of soda. It is supposed to be associated with common salt, but none of the many specimens I have analyzed, contain more than a trace of that compound. Vegetable colouring matter, carbonate of lime, alumina and sand in variable proportions constitute the remainder of this valuable mineral.

When treated with water in the mode described at page 180, the *sáji mati* yields its carbonate and sulphate of soda and colouring matter. By evaporating the washings to dryness in an iron vessel, mixing the residue with one-fourth of its weight of charcoal, and heating it to redness, the sulphate of soda is converted into sulphuret of sodium, which by further heating and slow cooling in free contact with the atmosphere, is changed into carbonate of soda. The colouring matter is destroyed also by this process, so that another series of washings afford a solution from which perfectly pure and colourless carbonate of soda can be obtained in octohedral (eight sided) crystals. For all ordinary purposes incineration of the simple mineral without charcoal will give a sufficiently pure product. Many specimens moreover contain no sulphate.

In various parts of Europe, especially in the Spanish seaports, and at Teneriffe, a fine soda is manufactured by burning some varieties of plants which grow near the sea coast, especially the *salsola soda* and *salicornia herbacea*. The soda thus procured is called *barilla*, and still constitutes an important item in British trade. In Scotland and Ireland a very impure soda called *kelp* is made by incinerating sea-weed of every kind.

But the chief supply of soda for the glass worker and soap-boiler is now afforded by the decomposition of sulphate of soda, when it can be cheaply obtained, or from the still cheaper substance, common salt. To convert this into carbonate of soda it is first decomposed by sulphuric acid, and the sulphate thus formed is mixed with saw-dust and carbonate of lime, and heated in a reverberatory furnace. A carbonate of soda is obtained by washing the incinerated mass.

The carbonate of soda effloresces or whitens on exposure to the air; when heated it dissolves in its water of crystallization. It is soluble in two parts of cold and less than its own weight of hot water. The solution is strongly alkaline in all its properties.

The *bi-carbonate of soda* is formed by passing a current of carbonic acid gas through a solution of the salt just described. It is less soluble than the carbonate, and requires ten times its weight of cold water for its perfect solution.

The *sesqui-carbonate of soda* is a natural production, found chiefly in Africa, where it is called *Trona,* and in South America, where it is named *Urao.* It contains 2 eq. of soda and 3 eq. carbonic acid.

MANUFACTURE OF SOAP.

Soaps are compounds of animal or vegetable oils or fatty matters, with an alkaline base, in which the oily substance has undergone a change which can only be made intelligible by adverting briefly to the nature of oily bodies.

Oils are of two kinds, the *fixed* and the *volatile;* the latter term implying that the oil can be distilled without decomposition. Fixed oils again, are either of animal or vegetable origin. By the researches of Chevreul, animal oils are proved to consist of two substances, one called *stearine,* which is solid at common temperatures; the other *oleine,* which requires a great degree of cold to effect its solidification. In vegetable fixed oils a substance closely resembling stearine exists, and is called *margarine.*

Fixed oils boil at 600°, and then suffer decomposition, yielding in the open air carbonic oxide and acid, carburetted hydrogen and other gases. Heated in close vessels, the carburets of hydrogen are the chief products. Exposed to the air, the fixed oils attract and combine with oxygen, evolve carbonic acid, become rancid, and finally concrete into a dry mass. The period required to effect these changes varies with almost every oil. Thus olive oil enclosed in a glass vessel with oxygen was unaffected for five months, but then the absorption of oxygen commenced and continued for nearly four years, when 102 volumes of oxygen had disappeared.

By heating several oils to the boiling point, this tendency to absorb oxygen is so accelerated, that the oil when mixed with any solid powder, such as lamp black, carbonate of lead, &c. dries rapidly on exposure to the air. The first of these mixtures is *printer's ink;* the second class affords us an endless variety of oil paints.

Oils contain carbon, hydrogen, and oxygen, in variable proportions, averaging, however, 5 eq. carbon, 13 eq. hydrogen, and 1 eq. oxygen.

Stearine. This substance is an ingredient in several animal oils and fats, especially hog's lard and mutton suet. It is prepared by melting suet in a flask, agitating it with its own weight of ether or oil of turpentine, and when cold pressing out the ether. The insoluble part is stearine. It occurs in brilliant white plates, composed of carbon 3, hydrogen 3, oxygen 2; fuses at 129°, is soluble in boiling alcohol, and on cooling separates in white flakes. When acted on by potassa, it changes into stearic acid, and a substance called *Glycerine.*

Margarine exists chiefly in vegetable oils, and is distinguished from *stearine* by its fusibility in cold ether. With potassa, like stearine, it yields stearic acid and glycerine.

Glycerine is the sweet principle of oils. In preparing soap by means of potash, this substance is left in the liquor from which the soap has been separated. By neutralizing the alkali with sulphuric acid, and acting on the residue with alcohol, the glycerine is dissolved. On evaporation it is obtained as a sweet syrup, soluble in water and alcohol, and distinguished from sugar by its not being crystallizable, and its being insusceptible of the changes which convert ordinary sugar into alcohol.

The animal acids formed during the preparation of soap are chiefly three,—the margaric, oleic, and stearic acids.

Margaric and oleic acids. Where animal fat or fixed vegetable oils are boiled with potash or soda, the elements of the fat or oil are converted into one or more fatty acids and glycerine. The new acids combine with the alkali and form soap, and the glycerine remains in solution. The margaric and oleic acids are best prepared from soap made with potash and vegetable oil. The soap is well dried and acted on by alcohol, which dissolves the oleate and leaves the margarate of potash, and the salts thus separated are decomposed by any acid.

Margaric acid is insoluble in water, and hence is precipitated from a watery solution of the margarate of potash, by adding any ordinary acid. It is very soluble in hot alcohol, which deposits it on cooling in fine pearly crystals.

Oleic acid is best prepared from soap made with linseed oil and potash. The oleate of potash, prepared as above-mentioned, is decomposed by an acid, when the oleic acid is separated. It is a colourless oily fluid, lighter than water, in which it is insoluble. It is dissolved by alcohol in every proportion.

Both these acids form salts, of which the margarates and oleates of potash, soda, and ammonia are soluble in water, but those of the earths and metallic oxides quite insoluble in that fluid.

The *stearic* acid strongly resembles the margaric, and is prepared by converting pure stearine into soap and decomposing the stearate thus formed by an acid.

Soap. The soaps of commerce are of two kinds,—the *hard*, made with *soda* and oil or tallow; the *soft* in which *potash* is the alkali employed. Generally a small proportion of potash is used with the soda soaps to diminish the hardness of their texture.

An account of the manufacture of the well known white Castile soap will be the best guide to persons desirous of attempting the process in this country, since it is from a *vegetable* oil the Castile soap is prepared.

The usual proportions employed are 600 lbs. of oil, 500 lbs. of barilla (carbonate of soda) and 100 lbs. of lime. The lime is slaked and mixed with the barilla, water poured on the alkali, and the solution of caustic soda thus obtained, drawn off when it reaches the specific gravity of 1.143. This is called the first or *capital* ley. A second washing of the original materials gives a ley, specific gravity 1.110; and lastly by a third washing, a ley, specific gravity 1.060, is procured.

The oil is then poured into an iron boiler with a portion of the *third* ley, and the mixture boiled. The remainder of the third ley is then added slowly, and when this is consumed the second ley is gradually added. When the oil begins to thicken, a portion of the first or capital ley is added by degrees; the consistence of the mixture now increases remarkably, and the soap separates from the watery liquid beneath. Some common salt is now added, which facilitates the separation of the soap, and on withdrawing the fire when the materials have cooled, the soap collects at the top in a pasty mass. The watery liquid below is drawn off and reserved for washing the lime and barilla for making other leys.

The fire is now rekindled, and the remainder of the capital ley added gradually as before. Portions of the soap are taken out from time to time, and when on cooling it appears dry when rubbed by the finger, the mixture is again cooled, and the ley drawn off as at first. The soap is now removed to a melting pot, when it is liquefied by a gentle heat to allow some impurities and colouring matter to subside. The melted soap is lastly ladled into moulds dusted with finely powdered lime, and allowed to remain in the moulds until it is so hard as to resist the pressure of the finger.

By the process thus described, 600 lbs. of oil should yield 1000 lbs. of soap.

Soft soap is made much in the same manner. One cwt. of potash, 80 lbs. of lime, and 160 lbs. of oil are the requisite proportions. Various colouring matters are occasionally added, but they are not essential to the composition of the soap. Soda and common salt must be carefully avoided in this process.

English curd soap is made of tallow, soda, and potash. 13 cwts. of tallow, 6 cwts. of barilla, 3½ cwts. of potash, 4½ cwts. of quick lime, and 1 cwt. of salt produce 24 cwts. of fine white soap. *English yellow soap* differs from curd soap in containing rosin and palm oil. Dammer may be used instead of rosin.

For minute directions on this important subject, the reader may consult with advantage the article "Soap" in Ure's Dictionary of Arts and Manufactures, or Porter's American edition of Gray's Operative Chemist, vol. ii. p. 629.

SECTION III.

LITHIUM AND ITS OXIDE.

Lithium was obtained by galvanic decomposition. It resembles sodium in appearance. Its equivalent number is 6.4.

With oxygen it forms lithia, an ingredient in some minerals, especially in spodumene (a compound of silica, alumina, and lithia,) and some varieties of mica. As the latter contain potash also, the spodumene, which is a rare mineral, is employed for the preparation of lithia. One part in fine powder is mixed with two parts of fluor-spar, and the whole heated with strong sulphuric acid. The silica of the mineral is acted on by the hydro-fluoric acid and expelled in the gaseous state. The alumina and lithia unite with the sulphuric acid. The alumina is precipitated by ammonia, the solution filtered

On evaporation a mixed sulphate of ammonia and lithia remains, and by heating this to redness, the sulphate of ammonia is expelled and lithia obtained.

Lithia resembles potassa and soda in many of its characters, but it forms rather insoluble compounds with carbonic and phosphoric acids. From baryta, strontia, and lime it differs by forming soluble salts with sulphuric acid; and from magnesia it is distinguished by its carbonate forming a solution in water, having an alkaline reaction on coloured test-papers.

The alcoholic solution of the chloride of lithium burns with a red flame.

THE METALS.

CLASS I.—ORDER II.

SECTION IV.

BARIUM AND ITS COMPOUNDS.

Barium was prepared by Davy by making carbonate of baryta into a paste with water, placing a globule of mercury on the surface of the paste, and laying this on a piece of platinum communicating with the positive pole of a galvanic battery of 100 double plates. The negative wire (platinum) being in contact with the globule of mercury, a compound of mercury and barium is formed; on heating this in a vessel filled with nitrogen gas, the mercury is expelled and the barium remains.

Barium is of a dark grey colour, heavier than water, which it decomposes with effervescence; hydrogen being evolved and the oxide of barium, baryta remaining in solution.

The equivalent of barium is 68.7. Symbol Ba. With oxygen and chlorine it forms very important compounds. The salts of the oxide are also of considerable interest.

The *protoxide of Barium* is prepared by heating nitrate of baryta to redness. It is a grey powder, difficultly fusible, alkaline to the taste, and in its neutralizing effects; insoluble in alcohol, soluble, though sparingly, in water. Pure caustic baryta also forms with water a hydrate containing 1 eq. of water, and which may be exposed to a white heat without parting with the water thus combined. The hydrate of baryta is soluble in three times its weight of boiling and 20 of cold water. A saturated solution in boiling water deposits crystals composed of 1 eq. of baryta and 20 eq. of water.

Peroxide of Barium. This oxide is made by conducting dry oxygen gas over pure baryta at a red heat. A more convenient process is by heating four parts of baryta to redness in a platinum crucible, and then gradually adding one part of chlorate of potassa. Chloride of potassium and peroxide of barium are formed, the first of which is removed by cold water.

The *Chloride of Barium* (or muriate of baryta) is prepared by decomposing carbonate of baryta, or a solution of sulphuret of barium by muriatic acid. It crystallizes in flat, four-sided tables, bevelled at the edges, consisting of 1 eq. chloride of barium and 2 eq. of water, which are expelled at a temperature of 212°. It is insoluble in alcohol, 100 parts of water at 222° dissolve 78 of this salt, and deposit 35 on cooling.

The chloride of barium is much used as a test for sulphuric acid. It has also been employed in medicine as a remedy in scrofula and analogous diseases.

Sulphuret of Barium is formed most easily by heating the sulphate of baryta to redness with charcoal, or exposing it at that temperature to a current of dry hydrogen gas. If sulphate of baryta finely powdered be made into a paste with flour, and heated in a crucible to redness for two hours, this compound is also produced. Hot water dissolves out the sulphuret, and the solution if saturated deposits colourless crystals on cooling.

From this sulphuret of barium we can readily obtain most of the other compounds of the metal. Thus when boiled with the oxide of copper, double decomposition issues, sulphuret of copper is precipitated and baryta remains. With a solution of carbonate of potassa, the carbonate of baryta is formed, and sulphuret of potassium remains in solution. Nearly all acids decompose the solution of sulphuret of barium, sulphuretted hydrogen being expelled, and a salt of baryta formed with the acid employed.

SALTS OF BARYTA.

Sulphate of Baryta occurs as a natural mineral in very great abundance. It is commonly called *heavy spar*. It is formed whenever sulphuric acid or a sulphate is added to a solution of baryta. It is perfectly insoluble in most fluids, even in the strongest nitric acid. Strong sulphuric acid dissolves it in minute quantities, but deposits it again when diluted with water. The sulphate of baryta is composed of baryta 1 eq. 76.7, sulphuric acid, 1 eq. 40.1 = 116.8.

Nitrate of Baryta is much employed as a test for sulphuric acid. It is prepared by dissolving the powdered carbonate of baryta in dilute nitric acid. It crystallizes in octahedra, and requires but four parts of boiling or twelve of cold water for its solution. Heated to redness, it evolves oxygen gas and pure baryta remains. This salt is composed of baryta 1 eq. 76.7, nitric acid 1 eq. 54.15 = total 130.85.

Carbonate of Baryta occurs in great quantities in lead mines, and in mineralogical works is called *Witherite*. It is quite insoluble in water, and is decomposed by acids, forming with these their corresponding salts.

Acetate of Baryta is formed by dissolving carbonate of baryta in acetic acid. It crystallizes in six-sided prisms, and is deliquescent.

All the compounds of barium above described, except the sulphate, are powerful acrid poisons. The sulphate is harmless, solely owing to its great insolubility. In cases of poisoning by barytic preparations, sulphate of soda or magnesia constitutes a certain antidote, if administered in time.

SECTION V.

STRONTIUM AND ITS COMPOUNDS.

The metal STRONTIUM was obtained by a process similar to that described for the preparation of barium in the last section. Its equivalent number is 43.8, Symbol Str. The protoxide strontia is prepared from the native carbonate by a method like that for preparing baryta. So close an analogy, in short, exists between all the compounds of barium and strontium that it is sufficient to point out here the particulars in which these differ from each other.

The sulphate of strontia is more soluble than that of baryta. The salts of strontia are not poisonous. The alcoholic solution of the chloride of strontium burns with a fine red flame. The red light used with such superb effect in fire-works and theatrical exhibitions, is composed of nitrate of strontia, with about one-eighth of sulphur and one-sixteenth of charcoal. A small quantity of sulphuret of antimony and chlorate of potassa are mixed with it to render it more inflammable.

SECTION VI.

CALCIUM AND ITS COMPOUNDS.

Calcium, the metallic base of lime, was obtained by galvanic decomposition according to the method described in the 4th Section. Its combining equivalent is 20.5, hydrogen scale, 256 oxygen scale. S and several of its compounds are of great importance.

Protoxide of Calcium, commonly named lime, is obtained by exposing carbonate of lime in any of its numerous forms to a red heat, so as to expel its carbonic acid. It is a brittle white solid, acrid to the taste, extremely infusible, evolving intense light when strongly heated. It has a strong affinity for water; fresh burned lime when slaked with that fluid, giving out a great degree of heat, and combining with 1 eq. of water to form a *hydrate*, which differs from the hydrates of baryta and strontia in parting with its water at a red heat.

The hydrate of lime is more soluble in cold than in hot water, consequently on heating a saturated solution of lime, precipitation of lime occurs. Water at the freezing point dissolves just twice as much lime as that fluid at 212°. These facts are curious exceptions to the general law of the solubility of solid substances, and are analogous to what has been already mentioned with reference to the sulphate of soda.

Lime Water is prepared by agitating well burned lime with water, allowing the solution to stand for a few minutes and then decanting the liquor. It has an acrid taste and alkaline reaction on vegetable colours. It attracts carbonic acid rapidly from the air, forming an insoluble carbonate.

The most delicate test of lime is the oxalic acid, a substance of which a description is given elsewhere. The oxalate of lime is extremely insoluble in water. But as oxalic acid and its salts precipitate baryta and strontia also, other tests must be had recourse to, to distinguish these earths from lime. Thus the nitrate of lime is soluble, while the nitrates of baryta and strontia are insoluble in strong alcohol. The sulphate of lime, moreover, is soluble, though sparingly, in water.

The *Peroxide of Calcium* is a substance of little importance.

The *Chloride of Calcium*, or the muriate of lime, exists in sea-water and in many saline springs: is the residue of the process for preparing ammonia, (see that head), and may be made by dissolving lime or its carbonate in muriatic acid. It is a very deliquescent salt. When mixed with ice or snow it dissolves rapidly, and produces intense cold. It is used frequently for the separation of water or its vapour from gaseous mixtures, the gas being passed through tubes containing this salt.

The *Chloride of the oxide of Calcium,* or chloride of lime, (bleaching powder,) is prepared by exposing layers of fresh burned lime to chlorine gas, which is absorbed in large quantities. It is a dry white powder having a slight smell of chlorine. It is partially soluble in water; the solution bleaches very powerfully, and on exposure to the atmosphere evolves chlorine, and deposits carbonate of lime. When strongly heated, chlorine is evolved, and subsequently oxygen gas, and chloride of calcium remains in the retort. According to Dr. Ure, the bleaching powder is not a regular chemical compound. To ascertain the degree of bleaching power of specimens of this powder, the simplest mode is to provide a large quantity of a solution of indigo in sulphuric acid, and ascertain how many grains of each specimen of the powder is required to bleach a certain quantity, say two ounces, of the indigo liquid.

The *Sulphate of Lime* occurs in immense quantities, and in many varieties as a natural production. Alabaster, Selenite and Gypsum are all sulphates of lime, differing in form and in the absence or presence of combined water. When the hydrous salt is heated to 270°, it loses its 2 equivalents of water, and forms the well known substance Plaster of Paris, so called from its existing in great quantities at Montmartre, close to the French capital. When this substance is mixed with as much water as is required to make it into a thin paste, it regains the 2 equivalents of water lost by the calcination, and then hardens very rapidly. This property of *setting,* as it is called, renders the Plaster of Paris a substance of great value, enabling us to take accurate casts of coins, heads, &c., all the previous preparation required being the oiling of the surface to which the paste is to be applied.

The *Sulphate of Lime* is soluble in 450 parts of boiling, and 500 of cold water. It is frequently contained in springs, the water of which forms, consequently, an insoluble compound with soap, and is unfit for washing or domestic use.

Phosphate of Lime is the basis of the earthy matter remaining after the burning of bones, (see Phosphorus). A variety of urinary concretion, very frequently observed, and called the bone-earth calculus, is composed chiefly of this substance.

The *Carbonate of Lime* occurs in a vast number of varieties as a natural production. Marble, chalk, and limestone are composed exclusively of this compound. Iceland spar is carbonate of lime in splendid transparent crystals. The shells of eggs, and of moluscous, and testaceous animals are chiefly this substance; and the fine and valued concretions called pearls, are nothing more than carbonate of lime and animal membrane.

Carbonate of lime is insoluble in water, but is readily dissolved by that fluid when impregnated with carbonic acid. By boiling water containing carbonate of lime thus dissolved, when the excess of carbonic acid is expelled, the carbonate of lime is again precipitated.

SECTION VII.

MAGNESIUM AND ITS COMPOUNDS.

This section leads us to the consideration of a method recently devised for obtaining the metallic bases of several of the earths in larger quantities than they are procurable by galvanic decomposition.

The new method devised by M. Bussy consists in decomposing the chlorides of the metals by means of potassium. Thus the chloride of magnesium is mixed with some pieces of potassium in a glass tube, and the heat of a spirit lamp applied. Intense ignition ensues, the potassium combines with the chlorine, and the metal magnesium is obtained.

Magnesium is a brilliant white metal, malleable, (that is, it may be beaten into leaves), and fusible at a red heat. It undergoes no change in dry air, and may be boiled in water without oxidation. It burns brilliantly when heated to redness in dry air or oxygen gas. When acted on by dilute acids it is oxidized and dissolved, hydrogen gas escaping, and a salt of magnesia remaining in solution. The equivalent of magnesium is 12.7. 158.3 on oxygen scale. Several of its compounds are used as medicinal agents.

Protoxide of Magnesium, commonly called magnesia, is obtained by exposing carbonate of magnesia to a strong red heat. It is a white, earthy powder, devoid of taste or smell, very infusible; it forms a hydrate with water, in which fluid it is sparingly soluble, requiring 5,142 parts of water at 60°, and 36,000 parts of boiling water for its solution.

When pure magnesia is placed on moistened turmeric paper it causes a brown stain. With nitric and muriatic acids it forms deliquescent salts soluble in alcohol. The sulphate of magnesia is very soluble in water,—a circumstance which distinguishes magnesia from lime, baryta, and strontia. A dilute solution of a salt of magnesia is not precipitated by oxalic acid, by means of which re-agent magnesia may be distinguished and separated from lime.

The *Chloride of Magnesium* is prepared by dissolving magnesia in muriatic acid, evaporating to dryness, mixing the residue with an equal weight of muriate of ammonia, and projecting the mixture in successive portions into a red hot platinum crucible. When the muriate of ammonia is expelled, the chloride of magnesium remains in a melted state. On cooling it becomes a colourless mass, very deliquescent, and soluble in alcohol and water.

Sulphate of Magnesia, or the well known purgative Epsom salt, is prepared by the evaporation of some mineral waters, as those of Epsom; by decomposing bittern, (which contains muriate of magnesia) by sulphuric acid; by decomposing bittern by carbonate of soda, and treating the precipitate thus obtained by sulphuric acid; by dissolving carbonate of magnesia in this acid, or by acting with it on the magnesian limestone. This mineral exists in great abundance in many parts of India, especially in Sylhet. When treated with dilute sulphuric acid, sulphate of magnesia is dissolved, and the insoluble sulphate of lime remains. The best process by far is by boiling two ounces of powdered *magnesite* with one ounce of concentrated sulphuric acid and eight ounces of water.

The sulphate of magnesia is bitter and nauseous to the taste—crystallizes in prisms—is soluble in an equal weight of water at 60°, and in three-fourths its weight of water at 212°. It is decomposed by alkalies and alkaline carbonates, magnesia, or its carbonate being thrown down.

Carbonate of Magnesia is met with in the mineral state, when it is called *magnesite*. In this form it is abundant near Madras. For medicinal purposes carbonate of magnesia is prepared by adding a solution of the carbonate of potash or soda to the sulphate of magnesia. It requires 2,500 parts of cold water for its solution, but is dissolved readily by a solution of carbonic acid, a bi-carbonate being formed. When the bi-carbonate of potassa or soda, or of ammonia is added to a solution of sulphate of magnesia, no precipitate occurs, owing to the solubility of the resulting bi-carbonate of magnesia; but if heat be applied, the neutral carbonate is thrown down.

Murray's "Solution of Magnesia" is a very valuable medicine, less known than it deserves. It is prepared by dissolving carbonate of magnesia in water by carbonic acid under strong pressure. On exposure to the air, the solution effervesces like soda-water. The chief merit of the remedy is, that it enables us to take a limpid draught, instead of swallowing a mass of powder or thick paste. Murray's solution contains 17 grs. to the fluid ounce of carbonate of magnesia.

METALS.

CLASS I.—ORDER III.

METALLIC BASES OF THE EARTHS.

SECTION VIII.

ALUMINIUM AND ITS COMPOUNDS.

Aluminium is prepared by decomposing the chloride of aluminium by potassium in the manner described in the last section, merely substituting a platinum crucible for the glass tube. When quite cold, the crucible is put in a large glass full of water, when the saline matter dissolves and a grey powder composed of metallic scales subsides. These are pure aluminium. The metal thus obtained resembles platinum in appearance. It is difficultly fusible. Heated to redness in the open air, it burns brilliantly, yielding white aluminous earth, of great hardness. It is not oxidized by water, or even by sulphuric or nitric acids separately, at common temperatures; but these acids, when diluted with water, form alumina, and hydrogen is disengaged.

There is still much uncertainty about the combining proportion of aluminium. Dr. Turner considers that all its known compounds contain 2 eq. of the metal to 3 of the simple substance. On this supposition the oxide of aluminium contains 2 eq. metal (each 13.7, or 171.2 oxygen scale) 26.14, and 3 eq. oxygen, 24.

The *Sesqui-oxide of Aluminium* is the only known oxide of this metal, and is commonly known as *alumina*, or aluminous earth. As Dr. Turner observes, "it is one of the most abundant productions of nature; it is found in every region of the globe, and in rocks of all ages, being a constituent of the oldest primary mountains of the secondary strata, and of the most recent alluvial depositions." Alumina is the basis of clay, and sometimes, on the other hand, occurs in beautiful crystals, of which the ruby and sapphire afford splendid examples.

The familiar salt called Alum, a compound of sulphuric acid, alumina, and potash, is used for the preparation of alumina. Alum is dissolved in four times its weight of boiling water, carbonate of potash added, and the resulting precipitate well washed with hot water. As the alumina thus prepared still contains some sulphate of potash, it is re-dissolved in muriatic acid and precipitated by ammonia. This precipitate when well washed and heated to redness is pure alumina.

Alumina is a white, tasteless, and insoluble substance. It attracts moisture powerfully, and adheres closely to the tongue, or any moist surface. When mixed with water it forms a ductile tenacious mass, capable of being moulded into regular forms. In the art of the potter this property of alumina enables him to fashion his vessels into every shape.

Alumina is detected by its being separated from its saline combinations by alkalies and their carbonates, and the precipitate by the alkalies being re-dissolved by an excess of the alkaline base employed.

The *Sesqui-Chloride of Aluminium* is prepared by mixing pure alumina, charcoal, and sugar into a thick paste with oil, charring the mass in a covered crucible, and subjecting the residue heated to redness in a tube to a current of chlorine gas. The chloride of aluminium gradually sublimes in flaky crystals resembling talc.

Sulphates of Alumina. Two sulphates have been described by recent chemical authorities; one, the *ter-sulphate* occurs native in the Greek archipelago, and is soluble in water; the other, the sulphate, also occurs native—is insoluble in water, and parts with its acid when heated to redness.

The ter-sulphate is found in abundance in Nipal and Behar, where it is termed *silájit.*

Alum, or the sulphate of alumina and potassa *(Phitkari* پھٹکری Hind.) is prepared in England by burning a peculiar slate containing alumina, potassa and sulphuret of iron. The sulphur unites with oxygen, and the resulting acid with alumina and potassa produces alum. In Italy alum is manufactured from a similar mineral, but one free from iron, —a circumstance which renders the Italian alum of very great value. To both, however, some salt of potassa must be added, since there is not sufficient in the alum mineral employed. In India the *silájit* may be conveniently converted into alum by being mixed with the washings of the burned *seth*, or spent indigo plant, which contains a considerable quantity of potash.

Alum is composed of 1 eq. ter-sulphate of alumina, and 1 eq. sulphate of potassa. It has a sweetish astringent taste—is soluble in five parts of cold, and in its own weight of boiling water. It crystallizes in large octohedra, and the crystals contain 50 per cent. of water. On heating them they effervesce and give out their water, and at a red heat the acid is expelled.

Instead of the sulphate of potassa, the sulphate of soda or ammonia may be substituted; alum may also be made with ter-sulphate of iron, ter-sulphate of oxide of chromium, or ter-sulphate of manganese, having very nearly the same properties as the regular alum. The iron alum in particular, is identical in form, colour, taste, and numerical composition with the true alum.

The uses of alum are very numerous, especially in the arts of tanning, dyeing, and calico printing. Many instances of its utility will meet us as we proceed.*

Acetate of Alumina is made by adding acetate of lead to a solution of sulphate of alumina: sulphate of lead is precipitated and acetate of alumina remains in solution. This salt also is very extensively used, especially by dyers and calico printers.

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* For remarks on Native Pottery and its improvement, *see Appendix*.

SECTION IX.

GLUCINIUM, YTTRIUM, THORIUM, ZIRCONIUM.

Glucina is an earth found only in the euclase, emerald, and beryl. Chloride of glucinium yields with potassium a metallic powder. Eq. 26.5, hydrogen scale, or 331.4, oxygen scale. The beryl contains about 14 per cent. of the protoxide, Glucina. It is a white tasteless powder, insoluble in water, and forms with acids, salts which are distinguished by their sweet taste. Glucina is dissolved completely by a cold solution of carbonate of ammonia; and is precipitated by boiling, —a property which enables the analyst to separate it from alumina, with which it is associated in the gems above-mentioned.

Yttrium is the metallic base of the earth yttria, which is found in very small quantities near Ytterby in Sweden, and has been lately detected in the common Bohemian garnet called *pyrope*. Yttria is not soluble in potassa, is precipitated by yellow prussiate of potash, and its sulphate is of an amethyst colour.

Thorium was procured from a rare Norwegian mineral thorite, which contains 57 per cent. of the protoxide of this metal. This oxide thorium is distinguished from alumina and glucina by its insolubility in potassa, and from yttria by its giving a colourless sulphate.

Zirconium. The oxide of this metal exists in the Jargon or Zircon of Ceylon. Its salts are insoluble in potassa, and precipitated by ammonia. Its sulphate is colourless, and its neutral salts are precipitated as sub-sulphates when boiled with a solution of sulphate of potassa. By these properties the compounds of zirconium differ from other analogous substances.

SECTION X.

SILICIUM AND ITS COMPOUNDS—GLASS.

Silicium. The basis of silica or flint has been regarded as a metal rather on presumptive than positive evidence. It is prepared by heating the fluosilicic acid with potassium. It has a dark brown colour, is devoid of metallic lustre, does not conduct electricity, is incombustible in air or oxygen gas, and is not oxidized by the most powerful acids, or by ignition with the chlorate of potash. But when brought into contact with carbonate of potash or soda, it inflames and burns vividly, and it causes an explosion when dropped on a piece of hydrate of potassa, owing to the decomposition of the water of the hydrate, and the inflammation of its hydrogen gas. The equivalent of silicium is now held by the best authorities to be 22.22, on the hydrogen, 277.31 on the oxygen scale.

Silicic Acid, or the oxide of silicium, is the chief ingredient of flint, sand, quartz, rock crystal, and many similar substances. If rock crystal be heated to redness and thrown into water, it is readily reduced to a white powder, composed of nearly pure silicic acid. In this state it is insoluble in water. It does not affect the colour of test-papers, but it combines with and neutralizes alkalies, earths, and the oxides of the ordinary metals, forming compounds of the utmost importance. Silicic acid is composed of silicium 1 eq. 22.22, oxygen 3 eqs. 24.00 = 46.22.

If one part of silicic acid be heated with three of carbonate of potassa, carbonic acid is expelled, and a glassy mass remains, which is perfectly soluble in water. But if three parts of the silicic acid be used to one of carbonate of potash, and the mixture be melted at a red heat, the well known and invaluable substance *glass* is produced.

All the varieties of glass essentially contain silica, and owe their differences and quality to the alkali used, or to other matters casually present. Green bottle glass is made of river sand and common kelp, and its colour depends on oxide of iron present in the sand. Crown glass is made with a purer soda, and plate glass of the very purest ingredients. In flint glass a quantity of litharge or red-lead is added. Ordinary flint glass (such as that of drinking glasses) contains, according to Mr. Faraday, 50 per cent. of silicic acid, 33 oxide of lead, and 13 of potash. Peroxide of manganese and nitre are also often used with the other ingredients in order to oxidize any carbonaceous matter present, which would otherwise stain the glass. Many metallic oxides are also used for the colouring of glass: thus oxides of manganese or cobalt give a violet, iron a green, silver a yellow, arsenic and tin a white colour to the glass with which these substances are fused.

For an excellent popular account of the manufactures of glass and procelain, the student is referred to the volume devoted to this subject in Lardner's Cyclopædia. I trust we may soon see this valuable art cultivated in British India, where every facility for its introduction exists, where the demand for the article is immense and progressive, and where at this moment there is not a single glass-house.

THE METALS.

CLASS II.

METALS, THE OXIDES OF WHICH ARE NEITHER ALKALIES NOR EARTHS.

ORDER I.

METALS WHICH DECOMPOSE WATER AT A RED HEAT.

SECTION XI.

MANGANESE AND ITS COMPOUNDS.

The metal manganese does not occur in the native state, but is obtained in small quantities by forming the black oxide into a paste with oil, and heating the mixture in a covered crucible for two hours in a smith's forge. It is a hard brittle metal, of a greyish white colour, and granular texture. Its density is 8.013. It is very infusible, and attracts oxygen eagerly when heated in the air. Brought into contact at a red heat with water, hydrogen is evolved, and the protoxide of manganese formed.

The equivalent number of manganese is ascertained to be 27.7, or 346 on the oxygen scale. No less than five oxides have been discovered, of which two seem to partake of the nature of salts; that is, being compounds of one oxide acting the part of an acid and the other that of a base.

The *Sesqui-oxide*, composed of manganese 2 eq.=55.4, oxygen 3 eq.=24, is an abundant natural mineral, and is the residue of the decomposition of the peroxide of manganese, when heated in close vessels for the preparation of oxygen gas.

The *Peroxide* is the well known and useful substance, the "black oxide of manganese." In the native state it is often associated with water, silica, alumina, carbonates of lime, and barytes, and peroxide of iron. It is composed of manganese 1 eq.=27.7 and oxygen 2 eq.=16. When heated to redness it parts with ½ an eq. of oxygen and the sesqui-oxide remains. Boiled with strong sulphuric acid, 1 eq. of oxygen is expelled, and a sulphate of the protoxide of manganese formed. With muriatic acid, chloride of manganese and water are formed, and chlorine is disengaged.

The peroxide of manganese is of great utility in the arts, being employed in immense quantities in the preparation of chlorine for bleaching, in glass making, calico printing, and other arts. It is a cheap article, being sold retail in Europe for one anna the pound. It has recently been found in large quantities near Ajmere, where it is thought by the natives to be an iron ore.

The *Protoxide*, or green oxide, manganese 1 eq. 27.7, oxygen 1 eq. 8, is the base of the usual salts of manganese, and is prepared by heating the peroxide to redness in a tube, and subjecting it to a current of hydrogen gas. The protoxide is of a green colour, permanent in the air, readily oxidized to its maximum by exposure to heat and air. With cold dilute sulphuric acid it forms a colourless solution.

The *Red Oxide* (manganese 3 eq. oxygen 4 eq.) is a natural production, and may also be made artificially by exposing the sesqui-oxide to a white heat.

The mineral *varvicite* is a compound of manganese 4 eq., oxygen 7 equivalents.

MANGANESE ACIDS.

Of these there are two, the manganic and per-manganic acids. When peroxide of manganese is heated with carbonate of potash, the manganate of potash is formed. Thus prepared the manganate of potash has long been called the "mineral chameleon," because its solution passes rapidly through several shades of colour. On the first addition of cold water a green solution is formed, which quickly becomes blue, purple, and red. These changes are owing to the conversion of the green manganate of potash into the per-manganate of that base. The manganic acid is composed of manganese 1 eq. oxygen 3 eq. It has not been obtained in a free state, being converted into the peroxide and oxygen.

The per-manganate of potash is obtained by fusing chlorate of potassa in a platinum crucible, introducing a few fragments of hydrate of potassa, and then adding peroxide of manganese in fine powder. The mixture is kept for some time at a red heat, the residue acted on by boiling water, from which the per-manganate is deposited on cooling in opaque crystals, of black, lustrous appearance. Their colour in solution is a rich purple. When mixed with dilute nitric acid and boiled, oxygen is evolved and peroxide of manganese subsides. The per-manganic acid is composed of manganese 2 eq. oxygen 7 eq. It is obtained in the free state by decomposing the per-manganate of baryta by dilute sulphuric acid. Dr. W. Gregory has lately published the subjoined description of a new process for preparing this curious compound:—

" Take of peroxide of manganese 132 parts (3 atoms), of fused potash 147 parts (3 atoms), chlorate of potash 124 parts (1 atom). Dissolve the potash in a very small quantity of water, and add to the solution the oxide and the salt, previously in fine powder. Mix intimately so as to form a thin paste, which dry up and pulverize finely. Introduce the powder into a platinum crucible, (which may be filled, as there is neither melting nor frothing,) and expose the whole for half an hour to a very low red heat. By this the production of the green manganate of potash, which had taken place to a considerable extent during the exsiccation, is completed; while any hyper-chlorate of potash which may have been formed is destroyed.

" The green mass, a mixture of manganate of potash and chloride of potassium, is easily detached from the crucible. It is to be dissolved in a very large quantity of hot water, and when the solution has acquired a pure red colour, it is to be decanted from the hydrated peroxide, the formation of which accompanies the change of manganate into hyper-manganate of potash. The clear solution, evaporated rapidly until crystals appear, deposits on cooling a number of small crystals nearly black. These are to be washed with a little cold water, dissolved in a small quantity of hot water, and this solution, on cooling, yields crystals of the hyper-manganate of potash, chemically pure, and often ¾ of an inch long. They have a fine bronze colour and metallic lustre, and their solution in water possesses the most superb purple colour. I have always obtained, by the above process, a quantity of crystals equal in weight to one-third of the oxide employed.

" The mother liquids, on the addition of sugar, yield a large quantity of hydrated peroxide, which, with that separated by decantation, is very well adapted for a new operation.

" In this process, while the chlorate is economized, and the quantity of hyper-manganate increased, that of the chloride of potassium is diminished, and only half of the oxygen is lost."

The *Proto-chloride of Manganese* is the residue of the operation for preparing chlorine by peroxide of manganese and muriatic acid. Pure chloride of manganese is best prepared by mixing peroxide of manganese with half its weight of muriate of ammonia, and gradually throwing the mixture into a crucible heated to redness. Proto-chloride of manganese is formed, and may be dissolved in water and separated by filtration from the other substances present. The *per-chloride* is a curious compound. It is formed by mixing per-manganic and sulphuric acids with fused sea salt. The hydro-chloric and per-manganic acids decompose each other, and per-chloride of manganese is disengaged in the state of vapour, of a greenish colour, which by intense cold is condensed into a brown liquid. If prepared in a large tube the vapour displaces the air, and if the vapour be then poured into a moistened flask, a dense rose-coloured smoke appears, and muriatic and per-manganic acids are reproduced.

The *Per-fluoride of Manganese* is a gaseous compound formed by mixing one part of the mineral chameleon with half its weight of fluor-spar in a platinum vessel, and decomposing the mixture by strong sulphuric acid. When mixed with atmospheric air, a splendid purple colour immediately appears owing to the formation of per-manganic acid. In consequence of its yielding its fluorine with great readiness to other substances, this gas cannot be prepared in glass vessels.

SALTS OF MANGANESE.

The salts of the protoxide are colourless when pure, but they generally have a faint rosy tint, owing to the presence of some peroxide; their solutions are not precipitated by sulphuretted hydrogen, but hydro-sulphuret of ammonia throws down a reddish white sulphuret of manganese. The ferrocyanuret of potassium gives a white precipitate.

The salts of the peroxide are not crystallizable; their solutions are of a red colour, which is readily bleached by all substances having an affinity for oxygen gas, the per-sulphate being reduced to the state of proto-sulphate by such reagents.

The *Proto-sulphate of Manganese* is the residue of the preparation of oxygen from the peroxide and sulphuric acid. It occurs in crystals of a faint rose colour—is soluble in water but not in alcohol.

The *Silicate of the Sesqui-oxide* is a mineral found in considerable abundance, of a greyish black colour and metallic lustre. It contains in 100 parts—silicic acid 15, sesqui-oxide of manganese 75, alumina and peroxide of iron 6. It does not yield oxygen when heated, but it serves for the preparation of chlorine with muriatic acid.*

ANALYSIS OF MANGANESE ORES.

I insert an account of this analysis in the hope, that the abundant sources of this mineral in India will soon be made available in the arts.

Several modes of assay have been recommended, but the simplest and best with which I am acquainted is that recently described by Dr. Thompson, and which I can confidently recommend.

The manganese to be tested must be reduced to a fine powder, or brought into the state in which it is used by the manufacturers of bleaching powder. To determine its value, proceed in the following manner;—

Into a balanced Florence flask put 600 grains of water, and 75 grains of crystals of oxalic acid. Then add 50 grains of the manganese to be tested; and, as quickly as possible, pour into the flask from 150 to 200 grains of concentrated sulphuric acid. This is best done by having a given weight of sulphuric acid, say 210 grains, previously weighed out in

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* This mineral has lately been sold to me in the Calcutta bazars as "soormeh," the sulphuret of antimony.

a glass measure, counterpoised on one of the scales of a balance. You pour into the flask as much of the sulphuric acid as you can conveniently. Then, putting the measure again into the scale, you determine exactly how much has been put in.

A lively effervescence takes place, and carbonic acid gas is disengaged in abundance.

Cover the mouth of the flask with paper, and leave it for 24 hours; then weigh it again. The loss of weight which the flask has sustained is exactly equal to the quantity of *peroxide* of manganese in the powder examined. Thus, let the loss of weight be 34 grains; the quantity of peroxide of manganese in the 50 grains of the powder which was tested will be 34 grains; or it will contain 68 per cent. of pure peroxide of manganese, and 32 per cent. of impurity.

To understand the action thoroughly, the student must refer to the section on Oxalic Acid, which is a compound of I eq. carbonic acid (C. O^{2}.) and 1 eq. carbonic oxide (C. O.)

The oxalic acid acts on the peroxide by abstracting one-half of its oxygen, which converts it wholly into carbonic acid; hence the effervescence. 55 grains of pure peroxide of manganese would give out 10 grains of oxygen, which would convert 45 grains of oxalic acid into 55 grains of carbonic acid, which escaping, indicate, by the loss of weight, the quantity of carbonic acid formed. Now it happens that the weight of the carbonic acid formed is exactly equal to the quantity of peroxide of manganese, which gives out its oxygen to the oxalic acid. Hence the reason of the accuracy of the test.

In other words, an integral particle of peroxide of manganese gives out one atom of oxygen. This atom of oxygen combines with an integrant particle of oxalic acid, and converts it into two integrant particles of carbonic acid. As this carbonic acid escapes, the loss of weight must be just equal to the quantity of peroxide of manganese in the powder subjected to the experiment.—*Thompson's Records of Science,* 1836.

The process is rendered more accurate by adopting a cork bent tube to the flask; in the tube are placed some fragments of chloride of calcium which absorb any watery vapour; the whole must be accurately weighed.

SECTION XII.

IRON AND ITS COMPOUNDS.

Although it is impossible, in an elementary manual, to enter into more than a mere outline of the numerous details essential to the study of this inestimable metal, I still hope to render this section of some use to the practical student. I shall not attempt an account of the preparation of iron on the large scale, but limit myself to the consideration of its manufactured varieties, and of such of its preparations as are useful in medicine and the arts.

The natural sources of iron are nearly infinite. In almost every rock, and soil, and water, the chemist can detect its presence. It is an ingredient of the stones which occasionally fall from the air; and the structures of vegetables and animals contain it in such abundance, that medals have been struck in the iron obtained from the ashes of the human body.

But it is to those substances alone which contain enough of iron to render its extraction economical, that the term "ore of iron" is applicable. Of these ores there are several species, of which the principal are those containing the red oxide, such as hematite—the black oxide, as the magnetic iron ore—or the clay iron stone in which the protoxide of the metal is associated with flinty and aluminous ingredients.

The principles on which iron is extracted from its ore are easily understood. To deprive it of its oxygen, carbon is used, and to separate the alumina and silica, lime is also added, because lime when heated to redness with these substances, fuses with them into a kind of glass, called "slag." The metal melted by the heat descends to the bottom of the furnace, and is drawn off in the fluid state. In this process the great object is to form an easily fusible mixture, and this can only be accomplished by varying the sort and quantity of materials according to the nature of the ore employed. Some ores contain lime; to these, it is obvious, little or less lime is to be added. These again are often deficient in sand, and this defect must be artificially remedied. Such objects are often fulfilled by mixing together ores of iron of different kinds.

The iron thus obtained is the "cast iron" of trade. It still contains carbon, silicon, aluminium, and phosphorus in very small quantities. It is very fusible and brittle. By exposure to the air at a red heat, its carbonaceous matter is oxidized and its earthy impurities mechanically separated. As this process advances, and the iron increases in purity, its fusibility diminishes and its tenacity increases. On cooling it assumes a grey colour, and fine metallic lustre. It is malleable, or may be beaten into sheets; ductile, or capable of being drawn into wires. When heated to redness it may be incorporated with a similar piece of iron by hammering or "welding." Its specific gravity is 7.8. One of its most remarkable properties is, that it is attracted by the magnet, exhibiting the phenomena of polarity and induction, alluded to in the introduction to this work.

To obtain iron in a state of perfect chemical purity, a more refined process than that above described must be had recourse to. The best method is by exposing the red oxide at a heat below redness to a current of dry hydrogen gas. Water is formed, and pure metallic iron remains in a state of spongy division. So extended, indeed, is the surface of the iron thus prepared, that it takes fire spontaneously in oxygen gas, or even in atmospheric air.

When exposed to moist air, iron rusts or combines with oxygen and carbonic acid. Heated to redness, oxygen is absorbed in abundance, and black oxide of iron formed. When brought into contact at a red heat with the vapour of water, oxide of iron is formed and hydrogen set free.

The equivalent of iron is 27.2 on the hydrogen, 399 on the oxygen scale.

The *Protoxide of Iron* (Ir. O. $=35.2$) is formed and converted into a salt when iron is acted on by dilute sulphuric acid. From the sulphate of iron thus prepared the oxide is thrown down as a white hydrate (rapidly changing to green) by alkalies, as a white carbonate by their carbonates, and as white ferro-cyanuret (changing to blue,) by the yellow ferro-cyanuret of potassium. In salts of the pure protoxide, solutions of gall-nuts (*máju-phal* ماجوپهل) cause no change of colour. But as the salts of the protoxide of iron rapidly absorb oxygen from the air and pass into the peroxide, it is with difficulty we can obtain the exact results above mentioned on the application of the enumerated tests. This oxide is attracted by the magnet.

The *Peroxide of Iron,* (Ir. 2 O_3 $=78.4$) occurs naturally in the mineral *hematite,* and is prepared artificially by heating the sulphate of iron to redness, or dissolving iron in dilute nitric acid, and precipitating the oxide by an alkali of any kind. It is not susceptible of magnetic action.

Peroxide of iron forms with the acids salts usually of a red colour. These salts yield a brown red precipitate with the alkalies, a fine blue with the yellow ferro-cyanuret of potassium, a deep blood-red with the sulpho-cyanuret of potassium, and a rich black with a solution of galls.

The *Black Oxide* (Ir. O $+$ Ir. 2 O_3,) is a mixture of the protoxide and peroxide. It is formed when iron is burned in oxygen gas, or heated to redness in the open air, or in an atmosphere of watery vapour; also by precipitating by ammonia a filtered solution of proto-sulphate of iron which has been exposed to the air in shallow vessels till no further deposit of the red oxide takes place. On treating this mixed oxide with dilute sulphuric acid, sulphates of the protoxide and per-oxide are formed, and may be separated by alcohol, in which the first is insoluble.

The natural magnet is an iron ore, containing protoxide and peroxide of iron, alumina, and silicious matter, and generally oxide of titanium. It has been found recently in considerable masses by Dr. Benza in the Neilgherries. It is the *chamuk patthar* چمک پتھر of the Hindus.

The *Proto-chloride of Iron* is made by acting on iron by muriatic acid. Hydrogen is set free, and proto-chloride of iron obtained on evaporation. The solution of this chloride in water rapidly attracts oxygen from the air, and an insoluble peroxide of iron is precipitated. The *per-chloride of iron* is best obtained by dissolving peroxide of iron in muriatic acid. On evaporation it separates in red crystals, soluble in water, alcohol, and ether. The valuable medicinal tincture of the per-muriate of iron is prepared by dissolving these crystals in strong spirit.

The *Proto-iodide of Iron,* a very effectual medicine, is made by mixing iodine, water, and fine iron wire together, and allowing the materials to remain in contact for two or three days, at a temperature of about 100°. On evaporating the solution to dryness at a gentle heat, the iodide of iron fuses into a dark grey mass, very deliquescent, and soluble in water and alcohol. To preserve the solution for use, it is recommended to keep a piece of iron wire in the bottle. This prevents the formation of peroxide of iron, which would otherwise occur by the absorption of oxygen from the air.

Sulphurets of Iron. The bi-sulphuret, or *iron pyrites* of mineralogists is a very abundant substance, especially in the vicinity of coal formations. It occurs in yellow cubes, or silvery radiated nodules. This compound is dissolved by nitro-muriatic acid, and is unaffected by the other acids. When exposed to heat in close vessels, it loses half its sulphur, and is changed into the proto-sulphuret.

The *Magnetic Iron Pyrites* is a natural compound of the proto-sulphuret and bi-sulphuret. Proto-sulphuret of iron is formed artificially by heating the bi-sulphuret to redness in close vessels, or by melting iron filings with half their weight of sulphur. It is soluble in dilute sulphuric acid, giving out abundance of sulphuretted hydrogen gas.

The *Carburets of Iron* are chiefly three; *graphite*, *cast-iron*, and *steel.*

Graphite, also called *plumbago*, or by a strange misnomer, *black lead*, occurs in the mineral state, and is found in great purity in the celebrated mine of Borrowdale, in Cumberland. It is composed of carbon, with from 5 to 10 per cent. of iron. The fine kind is used for making pencils; the inferior variety is reduced to a fine powder, and employed in polishing iron-ware, and preserving it from rust; in the manufacture of crucibles, &c. It is quite infusible, is of an iron-grey colour, and metallic appearance.

Cast Iron is of two kinds, the *white* and *grey:* the former is very hard and brittle, the latter softer and tenacious. Both are very nearly of the same composition, and the white may be changed into the grey by exposure to a strong heat and subsequent slow cooling—while the grey may be converted into the white by being heated and rapidly cooled. Cast iron contains from 3 to 5 per cent. of carbon.

Steel is an artificial carburet of iron, prepared in Europe by a process called cementation. A large furnace is filled with alternate layers of the best bar iron and powdered charcoal, the air excluded, and the contents of the furnace kept for several days at a red heat. The iron combines with from one and one-third to one and two-thirds of carbon per cent. A similar combination may be effected by exposing heated iron to a current of coal gas. The carburetted hydrogen is decomposed, its carbon unites with the iron, and its hydrogen is disengaged.

Steel is extremely hard and elastic, but little malleable or ductile, of dense texture, and capable of being highly polished. It is more fusible than the pure and less so than the cast iron.

It appears from the experiments of Messrs. Stoddart and Faraday, that the celebrated *Wootz,* or Indian steel, is an alloy (or metallic compound) of steel with silicium and aluminium. They succeeded in preparing a similar compound from these ingredients. Steel also combines with silver in forming an alloy, which with only one-five-hundredth of silver, is superior to *wootz* in hardness, but deficient in tenacity. Both these properties are combined in an alloy of steel with 1-100th part of platinum.

SALTS OF IRON.

The *Proto-sulphate of Iron* is a salt of much consequence in the arts, being used in the manufacture of ink, in dyeing, tanning, and in the preparation of the fuming sulphuric acid.

On the large scale this sulphate is prepared from native sulphuret of iron. This substance is made into large heaps, and exposed to the rains, the water which flows through being received in deep reservoirs. In about six months the sulphuret is converted into proto-sulphate of iron. The mass is then washed in the same manner as saltpetre earth, the waters evaporated, and the exhausted sulphuret again heaped up and exposed to the air. The evaporation is conducted in leaden pans, and as the solution is frequently very acid, some pieces of old iron are thrown in during the evaporation.

When pyritic slate or schist is employed instead of the nodular pyrites, sulphate of alumina remains in the solution after the sulphate of iron has separated. By adding sulphate of potash to this residual liquor, a copious product of fine alum is obtained.

The Proto-sulphate of iron (*heerá kásis* هراكسيس green vitriol, or green copperas) is common in all Indian bazars. It contains 1 eq. of sulphuric acid, 1 eq. of protoxide of iron, and 7 eq. of water. It is of a strong astringent taste, reddens the vegetable blues, is insoluble in alcohol, but dissolves in twice its weight of water. The solution absorbs oxygen rapidly from the air, peroxide of iron being formed. It crystallizes in green transparent rhombic prisms.

Small quantities of this sulphate are easily prepared for experiment by acting on iron filings with dilute sulphuric acid. Hydrogen gas is disengaged, and the salt required crystallizes from the solution.

The reader is referred again to the article on the manufacture of sulphuric acid, where an account is given of the decomposition of this salt by heat.

Per-sesqui-Nitrate of Iron may be made by mixing in a bottle an ounce of iron filings, an ounce of nitric acid, and four ounces of water. The liquid acquires a deep brown colour and sesqui-pernitrate of iron is formed, containing 80 peroxide of iron and 162 of nitric acid,—being in the proportion of 1½ acid to 1 peroxide of iron. When the solution is evaporated to dryness at a gentle heat, the residue dissolves in alcohol, and the solution constitutes an astringent remedy of great use in the treatment of the diarrhœas and chronic dysenteries of this country.

The *Carbonate of Iron* is much used in medicine. It is best prepared by dissolving 144 grains of crystallized carbonate of soda in water, and pouring into this a solution of 139 grains of the green sulphate of iron in one ounce of water. Sulphate of soda remains in solution, and the precipitated carbonate of iron is washed on the filter with hot water.

A solution of carbonate of iron in water may be obtained by passing a current of carbonic acid gas through water in which carbonate of iron is diffused; a soluble bi-carbonate of iron is formed.

The *Tartrate of Potash and Iron*, an old and useful remedy, is prepared by mixing two parts of cream of tartar with one of iron filings, moistening the mixture with water and exposing it to the air for some days. The iron is oxidized, and the oxide combines with the excess of acid in the bitartrate of potash.

Ink (European writing ink), is prepared by boiling two ounces of log-wood in chips, (the sapan wood of the bazar will answer nearly as well,) with four ounces of gall-nuts, *(máju-phal)* reduced to coarse powder. The solution is strained, and then are added two ounces of green sulphate of iron in powder, half an ounce of sulphate of copper, an ounce and a half of gum-arabic, and half an ounce of sugar. The mixture is to be well stirred, and bottled after it has remained at rest for twelve hours. In this process the gallic and tannic acids contained in the log-wood and galls, unite with the oxides of iron and copper, forming a black compound which is kept in suspension by the sugar and gum. The sulphate of copper is not essential, but it improves the tint of the ink.

Ink thus prepared is bleached by chlorine, and by several acids, especially the muriatic and oxalic. The stains on linen caused by ink, and called *iron moulds*, are formed by the peroxide of iron, and are effectually removed by oxalic acid without injury to the fabric.

SECTION XIII.

ZINC AND CADMIUM AND THEIR COMPOUNDS.

Zinc, the *Spelter* of commerce, (*dastá* دستا Hindustání,) is generally obtained from the ores called *calamine* and *zinc blende*—the former substance being a carbonate, the latter a sulphuret of the metal. When the latter is heated to low redness, and exposed in that state to the air for some time, its sulphur is dissipated and oxide of zinc is formed. From this as well as from calamine, or the native carbonate, the metal is procured by mixing the ore with charcoal, and heating the mixture in a large crucible closed above, provided with an iron tube led through the bottom, the upper orifice of the tube being above the contents of the crucible, and the lower aperture being nearly in contact with a vessel of water.

The vapour of the zinc with other gaseous substances descends through the tube and is condensed by the water. The first portions received generally contain arsenic and cadmium; the latter, besides these metals, are associated with lead and iron, sulphur, and occasionally copper. The mixture may be purified by distillation from iron or earthen vessels.

Zinc is of white colour, metallic lustre, highly crystalline texture. Specific gravity 7: very hard and brittle when cold, but malleable and ductile at a temperature ranging between 210° and 300°. Heated in close vessels it sublimes unchanged. In open vessels it fuses at 773°, then inflames and burns rapidly, emitting a fine white light, and copious clouds of finely divided white oxide, the substance termed by the old writers *philosophers' wool.* Zinc is oxidized and dissolved by dilute sulphuric and muriatic acids. The combining equivalent is fully established to be 32.3, oxygen scale, 403.2.

The remarkable voltaic relations of zinc, and the important part it bears in the construction of galvanic apparatus, are fully entered upon in the chapter on the chemical effects of electric currents.

The *Protoxide of Zinc* is obtained by the combustion of the metal, or by heating the carbonate to redness, or by precipitating the sulphate of zinc by an alkali. This oxide is white while cold, but becomes yellow when heated, the yellow colour disappearing again as the temperature falls. It is insoluble in water, forms salts with acids, and also combines with some of the alkalies.

The *Chloride of Zinc* has recently attracted much attention as an application to cancerous sores. It is prepared by dissolving zinc in pure muriatic acid, evaporating and fusing the residue in a porcelain crucible. It is a very deliquescent substance, and, owing to its peculiar appearance, is commonly termed the *butter of zinc.*

The *Sulphuret of Zinc* or *zinc blende* is an abundant mineral of various colours. It may be made artificially by heating the sulphate of the oxide of zinc to redness with charcoal.

For several important compounds of zinc with other metals, see the section "Alloys."

SALTS OF ZINC.

The salts of zinc are distinguished by their yielding with the alkalies a white precipitate, soluble in an excess of the alkali, by giving a white precipitate with the alkaline carbonates and hydro-sulphurets, and, when in neutral solution, with sulphuretted hydrogen.

The *Sulphate of Zinc* (سفید ٹوتیا *sufaid tutiyá*) is the residue of the process for making hydrogen by zinc and dilute sulphuric acid. It is also prepared by roasting the native sulphuret of zinc, and exposing it to heat and moisture. It crystallizes in transparent colourless four-sided prisms, soluble in 2½ parts of cold and 2 of hot water.

The sulphate of zinc is commonly sold in the Calcutta bazars instead of Epsom salts (Sulphate of magnesia) which it much resembles. Dissolve a portion in water, add water of ammonia freely, precipitates occur in both, but that from the zinc salt is re-dissolved by the ammonia. Take a particle of the precipitate when first formed and place it on a piece of red-hot charcoal. If zinc be present, it becomes of a vivid yellow while hot, resuming its white colour as it cools.

The *Acetate of Zinc*, a substance sometimes used in surgical practice, is prepared by decomposing a solution of 60 grains of sulphate of zinc by a solution of 80 of the acetate of lead. Insoluble sulphate of lead is precipitated, and acetate of zinc remains in solution.

CADMIUM.

This scarce metal occurs chiefly in association with the ores of zinc, during the reduction of which it is obtained. In colour and lustre it resembles tin. It is very ductile and malleable. It is very volatile, and its vapour condenses into minute globules resembling mercury. Its equivalent number is 58. Its oxide is of an orange, its sulphuret a yellow colour. The sulphuret is insoluble in alkalies, and is not volatilized by heat. These characters are important, inasmuch as they enable us to distinguish cadmium from arsenic in certain legal inquiries, of which an account is given in another section.

SECTION XIV.

TIN AND ITS COMPOUNDS.

The *Tin* of commerce (قلعي *qalaí*, Hindustání) is of two kinds, the *block* and *grain* tin, both of which are obtained from the native oxide by heat and charcoal. Tin has a white colour, fine lustre, is very malleable, but little ductile or tenacious. It is soft and inelastic, and when a long strip of pure tin is bent in different directions, it gives a peculiar crackling sound. Its specific gravity is 7.3. It fuses at 442°, and at a white heat takes fire and is converted into the peroxide of tin. Its equivalent number is 58.9. oxygen scale, 735.3. Tin may be reduced to fine grains by melting it in an iron ladle, pouring the melted metal into a wooden box well fitted with a cover and chalked on the inside, and agitating the melted metal until it has cooled. Thus prepared the metal is called "granulated tin," and in this state is an old remedy of some celebrity in the treatment of worm diseases.

The *Protoxide of Tin* is prepared by adding an alkaline carbonate to a solution of the chloride of tin. This oxide is white, and its salts attract oxygen with great avidity from the air, water, acids, or highly oxygenized salts. The persalts of mercury, silver, or platinum, yield all their oxygen to the protosalt of tin, and the respective metals are thrown down. With a solution of gold a purple precipitate is occasioned, called the purple powder of Cassius, composed of peroxide of tin and protoxide of gold, a substance well known in the arts of enamelling and porcelain painting.

A sesqui-oxide of tin has been recently described, but its properties are but of little importance.

The *Peroxide of Tin* is obtained by pouring concentrated nitric acid on small pieces of tin. No action ensues, but on adding a little water, violent effervescence occurs, nitrous acid and nitric oxide are evolved, and a white powder subsides which, when well washed and heated to redness, is the pure *anhydrous* peroxide of tin. Some ammonia is formed during the action above described, by the nitrogen of the acid and hydrogen of the water employed. The peroxide thus prepared is insoluble even in the strongest acids. It seems even to have weak acid properties uniting with alkalies, forming compounds termed "Stannates" from stannic acid. *Stannum* being the Latin name of tin.

The *Hydrated Peroxide* is prepared by adding a solution of any alkali to a solution of the perchloride of tin. This hydrated oxide differs in several respects from the anhydrous. It dissolves in and neutralizes the acids, but often separates from the solution again as a bulky gelatinous hydrate. Neutral solutions of this peroxide are precipitated *yellow* by a current of sulphuretted hydrogen gas—a fact deserving recollection in connection with the detection of arsenic, to be subsequently described.

The *Proto-chloride of Tin* is prepared by passing muriatic acid gas over tin heated to redness in a glass tube, or by distilling equal weights of corrosive sublimate (bi-chloride of mercury) and granulated tin. Thus prepared, it is a grey solid, which fuses below redness, and sublimes at a high temperature. A solution of proto-chloride of tin may be obtained also by heating granulated tin* in strong muriatic acid as long as hydrogen is evolved. This solution is used to withdraw oxygen from other metallic solutions.

The *Bi-chloride of Tin* is made by heating the protochloride in chlorine gas, or by distilling 8 parts of granulated tin with 24 of bi-chloride of mercury. It is a volatile, colourless, fuming liquid, called by the older writers the *fuming liquor of Libavius*, its discoverer. It boils at 248°. With one-third of water it becomes a solid hydrate, and with a larger quantity it dissolves.

The solution is manufactured in very large quantities for dyeing, by dissolving tin in nitro-muriatic acid. Two measures of nitric, one of muriatic, and one of water should be used, and the tin gradually added. These precautions are essential; for if the acid be too strong, or the tin added in too large proportion at once, the peroxide is deposited and is re-dissolved with great difficulty.

Some details as to the uses of this valuable compound will be found under the head of "Vegetable colouring principles."

The *Sulphurets of Tin* are three, the *proto-sulphuret* is black, the *sesqui-sulphuret* of a greyish yellow, but neither of any importance.

The *Bi-sulphuret of Tin* is the curious substance familiarly called *Mosaic gold*. It is prepared by heating to low redness in a glass retort, two parts of peroxide of tin, two of sulphur, and one of muriate of ammonia. The heat is to be continued until sulphurous acid gas ceases to be evolved. A still better method is by melting together twelve parts of tin with six of mercury, then triturating these in a mortar with seven of sublimed sulphur and six of sal ammoniac. Heat the mixture in a glass flask on a sand bath till white vapours cease to be evolved. Then heat to low redness, sulphuret of mercury

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* The tin foil of the bazar contains lead, and must not be used. The Malacca or Pegu tin is quite pure.

and chloride of tin sublime, and the mosaic gold remains at the bottom of the flask.*

The bi-sulphuret thus prepared is in scaly or tabular crystals, of a golden colour and metallic appearance. It is soluble in potassa or its carbonate, but insoluble in acids, with the exception of the nitro-muriatic.

SECTION XV.

COBALT—NICKEL.

Cobalt is obtained from *Zaffree*, an impure oxide of cobalt. The ore is roasted to expel some sulphur and arsenic, and then heated in a crucible with thrice its weight of black flux. The alloy of cobalt thus prepared is still in a state of much impurity by admixture with arsenic, copper, and iron. For its purification a solution in any of the acids is precipitated by potash. The oxide thus obtained is dissolved in dilute muriatic acid and sulphuretted hydrogen passed through the solution. The arsenic and copper are thus precipitated. Iron still remains. To remove this, boil the solution with a little nitric acid. This step peroxidizes the iron, add carbonate of potash which precipitates a mixed carbonate of iron and cobalt. Oxalic acid will now separate the iron, leaving oxalate of cobalt undissolved. On heating this to redness the pure metal is procured.

Cobalt is a brittle reddish metal; specific gravity 7.83: is attracted by the magnet, and oxidized when heated in open vessels. Its equivalent number is 29.5.

The *Oxide of Cobalt* fused with sand and potash or soda, gives a fine blue glass, much used in the arts for colouring porcelain, earthenware, and glass, and commonly called *smalt*.

The *Muriate of Cobalt* in solution is used as a *sympathetic ink*. If we write on paper with it, when the solution dries

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* Kane's Elements of Chemistry, p. 608.

there is no trace of the characters ; but on the application of a gentle heat, or moistening with water, a fine blue colour appears. Mixed with muriate of iron, an ink is prepared and used for sketching landscapes. The foliage thus drawn seems withered and dead while cold, but on being gently warmed assumes a lively leaf-green colour.

NICKEL.

This metal is obtained either from the *copper-nickel* of mineralogists, a compound of arsenic and nickel, with traces of copper, sulphur, cobalt and iron ; or from *speiss*, a product casually formed during the smelting of cobalt ores in which nickel co-exists. It would be of little utility to give the very complex process by which the metal is separated from all these substances.

The celebrated *white copper*, or *pack-fong* of the Chinese, is a compound of 40 parts of copper, 25 zinc, 31 nickel, and 2 of iron. A curious product, called in commerce *meteoric acid*, resembling damasked steel of the utmost beauty, is prepared by making an alloy of steel with 5 per cent. of nickel.

Nickel is also a constituent, but to a minute degree, in aërolites or meteoric stones.

Nickel is a white metal, of strong lustre, ductile and malleable, specific gravity 8.27. It is attracted by the magnet—is very infusible, is oxidized at a red heat by nitric acid. Its equivalent number is estimated at 29.5 on the hydrogen, 369.7 on the oxygen scale.

The salts of nickel are precipitated green by ammonia. The precipitate is dissolved in excess of the alkali, the solution being blue. Yellow prussiate of potash gives a white precipitate.

THE METALS.

CLASS II.—ORDER II.

METALS WHICH DO NOT DECOMPOSE WATER, AND THE OXIDES OF WHICH ARE NOT REDUCED TO THE METALLIC STATE BY HEAT.

SECTION XVI.

ARSENIC AND ITS COMPOUNDS.

Arsenic is the metallic base of the well known and dreadful poisons of that name, and which are used so frequently for the perpetration of murder all over British India, that the student should consult this section with the utmost attention. He will learn from it the means of detecting with precision and infallibility the minutest quantities of arsenical preparations, and he will also find in it information regarding some important uses to which they have been recently applied. In treating of this subject, I wish that the distinction may be clearly made from the commencement between the metal arsenic, and the poisonous substances commonly called arsenic, which are in reality compounds of the metal with oxygen, sulphur, and other elements.

The metal arsenic is a rare natural production in the pure state, but combined with sulphur, iron, copper, antimony or cobalt, it exists in great abundance. On roasting these ores in a reverberatory furnace, the arsenic is expelled and oxidized, forming the protoxide or arsenious acid, the common "white arsenic," (*sufaid sambul* سفيد سنبل) of the bazars. From this oxide the metal is procured by heating it in a covered crucible with twice its weight of the black flux.

Arsenic is a brittle crystalline metal, resembling steel in colour or lustre. Its specific gravity is 5.88. It sublimes at

356° emitting a strong smell of garlic. During the sublimation if the process be performed with free access of air, arsenious acid is rapidly formed. On exposure to air and moisture, especially when heated, a dark powder called *fly*-powder, is produced, which has been shewn to consist of a mixture of the metal and its oxide.

The combining equivalent of the metal arsenic is 75.34, oxygen scale, 940.1.

Arsenic (the metal) combines with hydrogen, forming a very important gas called the arsenuretted hydrogen. It consists of 1 eq. of the metal and 1½ of hydrogen, or by volume half a measure of the vapour of the metal, and one and a half of hydrogen condensed into one volume.

Arsenuretted Hydrogen is prepared, in its concentrated and pure state, with great facility, by fusing zinc and the metal arsenic together, and acting on the alloy thus formed with strong hydro-chloric acid. Arsenuretted hydrogen is disengaged, the chloride of zinc remains in solution. The gas thus prepared is totally absorbed by a solution of sulphate of copper. Its specific gravity is 2.69. It is colourless : has an odour of garlic: is highly combustible when inflamed in contact with the air, burning with a whitish blue or *leaden-coloured* flame. During the combustion, the oxygen of the air converts the gas into arsenious acid and water. If the flame be directed on a cold surface near the burning jet, the metal arsenic is also deposited.

This gas, in its concentrated state, is extremely deleterious. A distinguished chemist, Gehlen, was poisoned by the accidental inhalation of a very small quantity. But we may prepare it in a diluted state, so as to examine its properties with great precision, by a process I will subsequently describe.

The *first oxide of Arsenic*, white or common arsenic, or arsenious acid, is a compound of 1 eq. of the metal arsenic, and 3 eq. oxygen. It occurs in vast quantities in commerce, being chiefly used as an ingredient in white enamels, as a poison for rats, and a preservative for specimens of natural history. In all the Indian bazars it is to be obtained with facility, being imported into this country from China and the Persian Gulf. It would be difficult to assign a sufficient cause for its abundance in the bazars. It enters it is true into the composition of some native medicines, but I fear it is usually sold for any but medicinal purposes.

Three varieties of this arsenious acid occur in the bazar: one, in heavy masses, resembling white porcelain; the second glassy, transparent, and colourless; the third, a white powder prepared from either of the former. All are identical in composition and in their poisonous properties.

The arsenious acid sublimes at 380°, its vapour is devoid of odour, and condenses on cool surfaces in minute octohedral crystals of diamond-like lustre, and perfectly transparent and colourless. Although statements to the contrary occur in several books, still in the opinion of Drs. Christison and Turner, for the correctness of which I can confidently vouch on my personal knowledge, the arsenious acid is destitute of any acrid taste, and at most has a faintly sweetish and acid flavour.

One thousand parts of boiling water dissolve 77.70 of white arsenic, and the solution cooled at 60° retains 30 parts. But the same quantity of water at 60° only dissolves 2.50 parts. If organic matters be present, such as milk, tea, the juice of meat, &c. this solubility is still further impaired. The medico-legal applications of these facts are of much importance. For instance, it frequently happens in cases of poisoning by arsenic that the fluids found in the stomach afford no trace of the poison, while it abounds in the solid matters obtained from that organ. In a case recently submitted to my investigation by the Coroner of Calcutta, the preparations connected with which are preserved in the College museum, while I could barely detect arsenic in the fluid contents of the stomach, I found the lining membrane of that cavity actually crusted with a layer of the poison.

The arsenious acid combines with and neutralizes alkalies and oxides forming salts termed *arsenites*. Those of potash, soda, and ammonia are colourless, very soluble in water, also in an excess of their own acid, and in nitric acid. The arsenite of the oxide of silver is *yellow* and insoluble, being precipitated when an arsenite of an alkali is added to a solution of nitrate of silver. The arsenite of the oxide of copper is *green* and insoluble, and is also formed by double decomposition, arsenite of potash, soda or ammonia being added to a solution of the sulphate of copper. The green precipitate is the well known paint *Scheele's green.*

The arsenious acid by itself does not decompose the nitrate of silver, or sulphate of copper. The nitric and sulphuric acid being superior to it in affinity for these oxides, it requires the force of double affinity to affect the decomposition. Thus a solution of arsenious acid may be poured into a solution of nitrate of silver or of sulphate of copper: no precipitate occurs, but if a drop or two of ammonia or any other alkaline solution be added, the arsenite of silver or copper is forthwith thrown down.

If ammonia be very gradually added to a solution of nitrate of silver or sulphate of copper, a precipitate of the oxide of silver or copper is formed. By cautiously adding more ammonia in minute quantities, the precipitate is redissolved. The solutions thus prepared have now the exact quantity of alkali present to neutralize the arsenious acid; so that, added to solutions of that acid, an arsenite of ammonia is formed, which, by double decomposition, reacts on and precipitates the silver or copper.

If a current of sulphuretted hydrogen gas be passed through a solution of arsenious acid, a copious yellow precipitate of the sulphuret of the metal arsenic is formed. This precipitate is soluble in alkalies and insoluble in acids, and when dried and heated with potash gives out arsenic in the metallic state.

There is a second oxide, the *arsenic* acid, but it is a substance of little importance.

The *Sulphurets of Arsenic* are *two*, the native yellow sesquisulphuret of arsenic called *orpiment*, (*hartál* هرتال Hind.; *Zarnekh zard* زرنيخ زرد Persian.) The red proto-sulphuret or *realgar*, (*lál sambul* للعس نبل Hind.) Of orpiment there are many varieties; one in fine golden coloured-scales, another in dense yellow stony lumps, a third in earthy-looking masses, called the *King's yellow*, a familiar paint.

DETECTION OF ARSENICAL POISONS.

The mode of detection of arsenical poisons has long been a topic of interest, and of considerable difficulty to the medical practitioner.

The chief cause of the difficulty, however, was not intrinsic in the subject, but dependent on the ignorance of the individuals to whom too often such investigations were confided; men who were utterly unpractised even in the rudest analytic researches, and but little conversant even with the theory of the operation they attempted to perform.

The principle by which we should be guided in our search for this, as for all other poisons, is simply this—We must endeavour to obtain the poison in such a state that we can form from it as many of its known chemical compounds as possible, and these possessed of the most striking, characteristic, and peculiar properties. Thus, if white arsenic be the poison, we should endeavour to obtain the arsenuretted hydrogen, arsenious acid, the metal arsenic, the *green* arsenite of copper, the *yellow* arsenite of silver, the *yellow* sulphuret of arsenic by the application of appropriate re-agents. When all these compounds are obtained, the evidence is peremptorily conclusive, and it is still decisive, though only the metal, the arsenious acid, and one or two of the coloured compounds be formed.

To accomplish these objects an elegant but practically difficult process was devised by Dr. Christison some years since. By this process the hundredth part of a grain of arsenic could be separated by an expert analyst from any mixture however complex,—a fact which, as Dr. Christison observes, will scarcely surprise those who recollect that a grain of gold can be divided by mechanical processes alone into 50,000 visible and characteristic parts.

DR. CHRISTISON'S PROCESS FOR THE DETECTION OF ARSENIC.

Dr. Christison's first object was to bring the arsenic into solution. This he accomplished by diluting the solid and liquid contents of the stomach with water acidulated with acetic acid, and by boiling the mixture. He next filtered the fluid to separate the solid parts, then added nitrate of silver by which any common salt, and much animal matter is removed from the solution, while the arsenious acid remains. Excess of silver should be removed by a little common salt. Thirdly, he filters again, and then transmits through the fluid a current of sulphuretted hydrogen gas. If arsenious acid be present, a yellow sulphuret of the metal arsenic is thrown down, and thus we obtain the first link in the chain of evidence required.

The sulphuret of arsenic is next collected, carefully dried, mixed with a little black flux, and introduced along a paper channel into a glass tube closed at one end, ¼ inch in diameter, 4 inches long, and of which it should occupy about ¾ of an inch.

The mixture is then heated gently by a spirit lamp flame not larger than a pea. Any moisture condensing in the tube is removed by a thin roll of filtering paper. The heat is now increased until the tube is at a low red heat. The arsenic then sublimes in the metallic state, and condenses as a steel grey crystalline crust on the interior of the tube. This constitutes the second and most important step.

The metal thus obtained is now more minutely examined, in order to identify it thoroughly. It is heated by the spirit lamp flame again, and chased from one part of the tube to another. When thus repeatedly volatilized, it combines with oxygen; arsenious acid is formed in brilliant octohedral crystals, which line the interior of the tube.

The tube is now cut by a file; a few drops of warm distilled water introduced and agitated over the crystals which are dissolved. The solution is divided on three watch glasses: ammoniacal-nitrate of silver gives a yellow precipitate, the arsenite of silver with the first; ammoniacal-sulphate of copper gives a green with the second; sulphuretted hydrogen water forms orpiment with the third.

Thus the metal arsenic, its sulphuret, arsenious acid, and the arsenites of silver and copper have been formed, and the evidence is quite incontrovertible. Fallacies may be without difficulty found for each of the tests separately considered. An ignorant analyst may confound charcoal, mercury, or even a stain on the glass, with the metal in question—he may mistake a *yellow* phosphate of silver, or the *green* carbonate of copper, for the arsenites of these metals, but no concurrence of blunders can ever array together *all* the results I have pointed out.

Dr. Christison's process was one, however, which few but expert manipulators could successfully carry through. In such hands it gave all the evidence above enumerated, from portions of arsenious acid not exceeding one-tenth part of a grain; but, on the other hand, I have known many European pupils in vain attempt the analysis though twenty grains were present. The fault, of course, lay with the experimentalists; still such facts suggested the necessity of searching for an easier process.

It is obvious too, that Dr. Christison's directions applied only to the arsenious acid, and would not detect the sulphurets of arsenic,—poisons often substituted for the acid, and which produce exactly similar effects. This was another reason which led many chemists to institute further researches on this subject.

The object has at length been most successfully accomplished by Mr. Marsh, of Woolwich, who has recently made the most valuable contribution to medico-legal chemistry, which has been published for many years. His process, with a modification introduced by the Editor of this work, as subsequently explained, embraces in one operation all the arsenical poisons. It procures the arsenic in the state of arsenuretted hydrogen, the metal, arsenious acid, the yellow arsenite of silver, the green arsenite of copper, and the yellow sulphuret of the metal. It detects the minutest particles of the poison, however intricate the mixture with which they may be united. It is so simple that the only apparatus required can be made in any locality in half an hour, and the process is moreover so free from difficulty, that no person of ordinary dexterity can commit an error. For this valuable paper Mr. Marsh has been presented with the gold medal of the Society of Arts. I now proceed to the details of the plan in question.

MR. MARSH'S PROCESS.

Mr. Marsh's process depends on the fact, that hydrogen gas, if disengaged slowly in contact with nearly all arsenical preparations of whatever kind, separates and combines with the metal, forming dilute arsenuretted hydrogen, by the examination of which all the chemical properties of the poison can be recognised.

If the substance for examination be a solution, it is mixed with very dilute sulphuric acid, and placed in a wide jar, of which it should fill about one-half. A piece of *pure* zinc is to be introduced; and a glass vessel open below and provided with a cork, and a piece of copper or brass tube with a fine aperture above, placed in the fluid over the zinc. The aperture in the tube is to be closed,—and the gas rising from the zinc accumulates in the glass vessel which thus acts as a gasometer, and the fluid it contains is gradually pressed upwards between its sides and those of the outer jar. The whole arrangement is shewn in the drawing, *fig.* 24. A small candlestick glass shade answers excellently for the central vessel. When a few cubic inches of gas have collected, the tube is to be opened to disengage the gas. This is done several times till all common air is expelled, otherwise an explosion would occur. After this a lighted match is applied. The flame should not be larger than a pea. If it be pure hydrogen, the gas burns with a scarcely visible blue flame; and if a glass tube or a piece of window glass be applied to it, the glass is covered with moisture, but receives no stain. But if the least trace of arsenic be present, the flame is remarkably altered, and is of a leaden white colour. Brought in contact with a piece of glass or porcelain, a black powder is deposited, (the fly-powder, a mixture of the metal and its oxide), and arsenious acid also condenses in a whitish circle round the dark spot. If a tube (half an inch in diameter and three inches long, open at both ends—a broken phial answers very well) be moistened on the outside, and the flame brought closely in contact with its inner surface, a fine brilliant crust of metallic arsenic is deposited. Above and around this crust a black powder is seen, and higher still in the tube, a white crystalline powder concretes. If we smell the tube while heated, the odour of garlic is very distinct. By applying the heat of a spirit lamp we can chase the metal all over the tube, and at length convert it into arsenious acid altogether. When it has cooled, we should introduce a few drops of warm water by which the crystals are dissolved. Divide the solution on watch glasses, apply ammoniacal nitrate of silver to one, ammoniaco-sulphate of copper to the second, hydro-sulphuret of ammonia to a third. In the first there will be a yellow, in the second a green, the third a yellow precipitate.

The series of tests above described, I have frequently obtained by operating on the fiftieth part of a grain of arsenic mixed with 40 ounces of water.

When much organic matter is present, as in the fluid and solid contents of the stomach and intestines, some inconvenience is experienced from the frothing up of the materials, which are thus projected into the tube and extinguish the flame. This is obviated by oiling the interior of the glass bell before commencing the experiment, and by allowing the contents of the vessel to stand at rest for some hours before inflaming the gas.

By the process just described, I separated arsenic in the metallic state from the *fluid* contents of the stomach in the case alluded to at the commencement of the section. The fluid in question, would not have yielded any satisfactory evidence of the poison, had it been examined by the ordinary method.

APPLICATION OF MARSH'S PROCESS TO THE SULPHURETS OF ARSENIC.

Since the publication of the first edition, I found during the investigation of a case of murder by orpiment that Marsh's process would not detect, either the sulphurets of arsenic or the alkaline solutions of these poisons.

As the yellow sulphuret is just as commonly used as a poison in India as the white oxide,* it became necessary if possible to extend Marsh's process to the detection of the sulphurets also. This I succeeded in doing as follows:—

Boil the suspected matter with strong and pure nitric acid in a clean porcelain vessel till all brown fumes cease to be evolved, evaporate to the consistence of syrup, and neutralize the acid with a solution of pure carbonate of potash, strain and dilute with a large quantity of distilled water. By this process the sulphuret of arsenic is oxidized by the nitric acid. Arsenic acid is formed and dissolved by the alkaline solution in the state of arseniate of potash.

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* While writing this sentence, a case of poisoning by yellow arsenic was admitted into our Hospital at the Medical College.

Marsh's process will detect the arsenic by this method in portions of the solution not containing $\frac{1}{1000}$th part of a grain of the poison.

Fallacies in Marsh's method.

The causes of error in the use of this admirable process are:—

1. The presence of arsenic in the zinc, acids, or potash employed. This is avoided by in every case testing the gas obtained from the zinc before adding the suspected matter, and by testing also equal quantities of all the materials employed.

2. Peroxide of iron, now much used as an antidote, sometimes contains traces of arsenic. The history of the oxide employed can usually be traced, and a portion should be tested if it could be procured. This fact should make all dispensary druggists careful to ascertain the purity of the article they vend.

3. Orfila has lately discovered traces of arsenic in the bones of the human body associated with phosphorus. This fact seems beyond a doubt. But I can add the most positive statement that the whole of the stomach and intestines may be subjected to the nitric acid and hydrogen process, without the slightest indication of arsenic being procured. I make this statement on the grounds of several trials—some in the actual course of criminal investigations.

Lastly. Tartar emetic and soluble antimonial compounds give antimoniated hydrogen, which deposits metallic antimony and white oxide of antimony when inflamed—An inexperienced person may readily confound this with the arsenical crust. I pointed out in the *Journal of the Asiatic Society*, for 1840, a certain method of obviating this cause of error—namely, by touching the crust with a glass rod dipped in solution of nitrate of silver, then holding it over a phial of ammonia. A canary yellow colour is immediately struck by arsenic, while antimony is unchanged.

I trust I may be pardoned for adding a word or two as to the introduction of this process to the notice of the profession.

The moment I read Mr. Marsh's notice, I at once saw its extraordinary value. I shewed the process at Government House the evening of the day on which I read it. That week I applied it in the investigation of two cases of arsenical poisoning received into the Police Hospital, and I was subsequently the first to publish the practical results of its application in legal analysis. Since then it has been adopted by Christison, Orfila, and all other toxicologists of repute; witness the Laffarge trial.[*]

ANTIDOTES TO ARSENIC.

There can scarcely be said to exist any substance entitled to be called an antidote to this poison. All its soluble and insoluble compounds are themselves poisonous, if we except perhaps the arsenite of the peroxide of iron.

The sulphuret of potash, powdered charcoal, and magnesia have at various times been recommended as specifics, but certainly on inadequate grounds. Very lately several experiments have been published, which seem to shew that the moist hydrate of the peroxide of iron, when given in large quantities soon after arsenic has been taken, prevents its poisonous effects. It seems also that the arsenite of the peroxide of iron is a harmless compound. The remedy is consequently worthy of trial. The peroxide of iron is prepared by adding potash or soda to the per-muriate of iron,

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[*] If the reader will refer to Dr. Corbyn's "*India Journal,*" he will find an amusing piece of criticism with which I was honored on the occasion by the sagacious Editor. A smart boy who had only studied *Pinnock's Catechism of Chemistry* for half an hour, could scarce have strung together such whimsical proofs of his total misconception of the subject on which he wrote.

and washing the precipitate. Two ounces or more diffused through water should be given to produce the effect described.

The hydrated peroxide of iron is best prepared by dissolving four ounces of good bazar sulphate of iron *(heera kasis)* in two parts of water acidulated with three fluid drachms and a half of strong sulphuric acid. Boil the acid solution, add in small quantities nitric acid, (sp. gr. 1.380), nine fluid drachms; on each addition boil the liquid, and do so till a little ammonia causes a deep brown precipitate. When the liquid is cold add three fluid ounces and a half of strong ammonia, agitate briskly, strain through calico and wash with water. Press the deposit and keep it in stoppered bottles in the moist state. Dose—half an ounce diffused through water, and repeated as required.

PRESERVATION OF ANIMAL MATTERS BY ARSENIC.

The property which arsenic possesses of suspending the putrefactive decomposition of animal matters has long been a matter of popular notoriety. A paste prepared with arsenic and camphor is in constant use in all museums of natural history for the preservation of skins and specimens. In toxicological works numerous instances are on record, of bodies of persons thus poisoned resisting the ordinary decay. But recently this property has been applied in a new and very interesting manner,—namely, to the preservation of the human body after natural death.

In May, 1836, an Italian physician tried the experiment of injecting a strong arsenical solution into the carotid artery of the deceased human subject. He found that decomposition was altogether prevented. In the most sultry weather, months passed by and still the body exhaled no offensive odour, but at length shrivelled and dried, so that it resembled the remains of those who perish in the sands of Arabia, or which have undergone the desiccation which occurs in some well known burial places in Europe.

On receipt of the journals containing the narrative of these experiments, immediate steps were taken for their repetition at the Medical College. On the 9th of March 1835, the body of a woman recently deceased was injected through the carotid artery with a solution of 1 lb. of arsenic in 12 lbs. of water. On the second day it was found by chemical analysis that the arsenic had penetrated through all the structures of the body. On that day it was also noticed that the flies which settled on the skin were killed. Six days passed before the least change was perceptible. About the seventh, the eyes lost their fullness, and the lips and fingers began to shrivel. In a fortnight the limbs had shrunk considerably, but still not the least offensive odour, nor any trace of decomposition could be detected. On the sixteenth day the body was opened and its internal structure examined. The brains, lungs, stomach, and intestines were as free from putrefaction as though the deceased had been alive but an hour before.

As far as the preservation of the body is concerned, it is consequently established by this experiment, that anatomical researches can be practised without inconvenience, even during the warmest weather in this sultry climate. It remains for further experience to denote whether the peculiarly close scrutiny to which anatomical objects are subjected will, in such instances, prove prejudicial to the health of the student. There are many facts on record, which seem to prove that the simple manipulation of animal substances impregnated with arsenic is extremely deleterious, and it is no less certain that the highly poisonous arsenuretted hydrogen gas must be slowly disengaged from bodies thus preserved. Under these circumstances the utmost caution must be observed, and numerous experimental trials performed before this system of preserving bodies for anatomical purposes can be recommended without qualification.

The experiments above described were conducted by my cousin, Mr. Richard O'Shaughnessy, at my suggestion.

September, 1841.—The use of the arsenical solution is now the regular practice of the Calcutta anatomical school. Each body on being received is injected from the aorta with the saturated solution of arsenic, and a day is allowed to intervene before the dissection is commenced. No decomposition ever ensues—the rooms are perfectly free from any offensive odour, though sixteen bodies are often under dissection at once. Not only has no indication of any deleterious influence on the students been shewn in a single case, but the usual ill effects of dissection punctures have entirely ceased in the class. The adoption of this method has been the chief cause of the success of the anatomical school of this College. Without it, dissection would be frequently impracticable.

There is still in the Museum the body thus treated in March 1835. It has become perfectly dried up, but the features are so little changed, that they seem almost alive. The hair has not separated from any part of the person. In the rainy season it becomes covered with green mould. Had it been coated with a film of wax varnish to prevent evaporation, it would have retained its original bulk and weight to this day.

The practice has been last year adopted in the Paris dissecting rooms, at the suggestion of a young French surgeon, who saw its effects in Calcutta. Its utility will doubtless be better appreciated in Paris than it has been here.

SECTION XVII.

CHROMIUM, VANADIUM, AND THEIR COMPOUNDS.

Chromium in combination with oxygen and lead or iron is a very abundant mineral in Europe and America, and has recently been found and applied to manufacturing purposes in Southern India. It is obtained by decomposing its oxide or chloride by carbonaceous matter, by the heat of a powerful forge fire. This metal is of a yellowish white colour, specific gravity 5.19; very brittle and infusible, and but little affected by strong acids. With oxygen chromium forms two compounds, the sesqui-oxide and chromic acid. Its equivalent number is shewn by the experiments of Berzelius to be 28.19, or 351.8 oxygen scale.

The *Sesqui-oxide of Chromium* is prepared by dissolving chromate of potassa in water, and mixing it with a solution of proto-nitrate of mercury. Proto-chromate of mercury subsides, and on heating this to redness the mercury is driven off and the chromic acid resolved into oxygen and the sesqui-oxide. The oxide is green, infusible, and insoluble in water or in acids. Heated with nitre or chlorate of potassa, it is oxidized to the maximum and forms chromic acid. With borax or silica and an alkali, it forms a fine green glass resembling the emerald, a gem which owes its colour to this oxide. This sesqui-oxide forms salts with the acids, which are easily prepared by boiling the chromate of potassa with equal measures of strong muriatic acid and alcohol, until the liquid assumes a fine green colour. By adding ammonia in excess a pale green oxide subsides, which is readily dissolved by acids, and forms the salts described.

Chromic acid is prepared by conducting the gaseous terfluoride of chromium (see that head) into a silver vessel moistened with water and closed by a piece of moist paper. Fine acicular crystals of chromic acid, of a rich red colour, are deposited in such quantities that they nearly fill the vessel. Or by precipitating a solution of bi-chromate of potash by a current of hydrofluo-silicic gas, evaporating the liquid to dryness, and redissolving in a small quantity of water, this again dried gives dry chromic acid. It is very soluble in water and in alcohol, but if heated in this fluid, or exposed to light, it is deoxidized and changed into the sesqui-oxide. It is a very strong acid, containing 1 eq. chromium, 3 eq. oxygen, and it forms salts called chromates. Its solution bleaches indigo and many other colouring principles. The chromate of lead is of a fine yellow colour, and is much employed for painting and dyeing.

The *Ter-chloride of Chromium* is formed by fusing bi-chromate of potassa with twice its weight of common salt, and decomposing the mass by strong sulphuric acid. A red vapour arises, which can be condensed as a heavy liquid, which evolves copious red clouds on exposure to the air, and is decomposed by water, yielding chromic and hydro-chromic acids.

The *Ter-fluoride of Chromium* is prepared by distilling from a leaden or silver retort 3 parts of fluor-spar, 4 of chromate of lead, and 5 of strong sulphuric acid. A gas is disengaged of a fine red colour, which by moisture is converted into hydro-fluoric and chromic acids.

SALTS OF CHROMIUM.

The chromates are either yellow or red, the latter colour generally indicating an excess of acid. Boiled with hydrochloric acid and alcohol, this acid is set free and then decomposed, a green solution of chloride of chromium being formed.

Chromate of Potassa is made by heating to redness the native chromate of iron, with one-fifth of its weight of nitre. The chromic acid unites with the potash and the nitric acid is decomposed. The chromate of potash is separated by solution in water and crystallization. This salt occurs in yellow crystals, is soluble in twice its weight of water at 60°, and insoluble in alcohol. It is composed of 1 eq. of acid, and 1 eq. of potash.

The *Bi-chromate of Potassa* is prepared for the dyers by adding dilute sulphuric or acetic acid to the neutral chromate, and allowing the solution to crystallize. It is of a fine red colour, and contains 1 eq. of the alkali and 2 eq. of chromic acid. By adding a solution of this salt to solutions of the nitrate of baryta, mercury, or silver, the acetate of lead, or sulphate of zinc, yellow chromates of zinc, baryta, and lead, red chromate of mercury, and purple chromate of silver are formed.

A *Bi-chromate of Lead* (1 eq. chromic and 2 eq. protoxide of lead) is prepared by boiling carbonate of lead with bi-chromate of potassa, or by boiling the neutral chromate with lime water and ammonia. This compound is of crystalline texture and superb red colour, and is extensively used as a lively, cheap, and durable paint.

The compounds of chromium above-mentioned deserve the attention of the pupil. As the arts develop themselves in India, the applications of the chrome colours will become very extensive; the more so, as the sources of chromium are abundant in the country.

VANADIUM.

Vanadium is a metal recently discovered in some ores of iron and of lead. The native vanadiate of lead is dissolved in nitric acid, the solution diluted with water, and the lead precipitated by a current of sulphuretted hydrogen. A blue solution of the oxide of vanadium remains, which on drying becomes vanadic acid.

From this acid the metal is obtained in small quantities by decomposition with potassium—or the liquid chloride of vanadium is placed in a bulb blown in a barometer tube, and through it is transmitted dry ammoniacal gas: muriate of ammonia is formed, and may be expelled by heat, and metallic vanadium remains in the tube. It is a silver-like metal, extremely brittle, not oxidizable by air or water, insoluble in boiling sulphuric, muriatic, or hydro-fluoric acids. It is dissolved by the nitric or nitro-muriatic acids, and the solution is of a blue colour. The equivalent of vanadium is 68.5.

The protoxide of vanadium is procured from vanadic acid by charcoal, hydrogen, and other deoxidizing substances at a moderate heat. It is of a black colour, and when pressed together is a conductor of electricity—a very unusual property in metallic oxides.

A binoxide of vanadium has also been described. Its salts are of a blue colour, soluble in water.

The vanadic acid is of an orange-red colour, fusible and crystallizable. It forms an extensive class of salts, none of which have as yet been applied to any useful purpose, except the vanadiate of ammonia, which, with a solution of galls, forms a very black ink, which possesses some excellent qualities. This ink is a perfect solution, and is unchanged by acids. Even chlorine affects it but very little, compared with the change it produces in the colour of ordinary inks.

The vanadic acid is distinguished from the chromic, which in many respects it strongly resembles, by the effects of deoxidizing substances, which give a blue colour with the former, and a green with the second of these compounds.

SECTION XVIII.

ANTIMONY AND ITS COMPOUNDS.

Antimony is a very important metal, and deserves attentive study. It is sometimes found in the metallic state as a natural production, but its chief source is the grey sulphuret, the *stibium* of the ancients, the *surma* سرمه of the Oriental bazars.

The *surma* is found abundantly in Nipâl, but the greatest part sold in the bazars is imported from the Straits and from Siam. It is commonly mixed with *galena*, or the sulphuret of lead, from which, however, it is easily distinguished, the antimony ore occurring in fine streaky, fibrous, crystalline masses of a radiated texture; the lead ore, on the contrary, being in cubic masses, destitute of rays, and cubical in its crystalline disposition. By heating a particle of the sulphuret of lead on charcoal before the blow-pipe flame, circles of a red and yellow colour, the oxides of lead, are formed on the charcoal, and lead is obtained in its characteristic soft state. The true *surma*, on the contrary, when heated on charcoal evolves abundant *white* fumes, and is reduced to the metallic state with much difficulty. The metal, when obtained, differs much from lead, as will be better understood by the perusal of the subsequent remarks.

The fused sulphuret of lead and arsenic—the sulphuret of molybdenum—and the silicate of manganese have been sold to us in the Calcutta bazar as sulphuret of antimony. The first gives the red and yellow oxide on charcoal, the second is totally unaffected by heat, the third when rubbed in a wedgewood-ware mortar gives a brownish red powder.

To prepare metallic antimony, the sulphuret is heated in a covered crucible with half its weight of iron filings—or it is reduced to powder, mixed with two-thirds its weight of cream of tartar and one-third of nitre, and the mixture thrown in small portions at a time into a red hot crucible. Sulphuret of iron is formed in the first instance, sulphate of potash and sulphuret of potassium in the second. The fused antimony collects at the bottom of the crucible, and may be drawn off into moulds.

Antimony is grey, brittle, specific gravity 6.7: fuses at 810°, and concretes in leafy crystals. It is not volatile, unless currents of gaseous matter pass through it while in a fused state, in which case particles of the metal are mechanically borne away with the vapour. Heated to redness in a covered crucible and then exposed to the air, it takes fire, and burns with a white flame, and the production of copious white vapours of the sesqui-oxide—the "argentine flowers of antimony" of the old writers. The equivalent of metallic antimony is 129·2 on the hydrogen, 16.13 on oxygen scale.

Chlorides of Antimony. When powdered antimony is thrown into a vessel of chlorine gas, the metal inflames, and the sesqui-chloride of antimony is formed. This chloride may also be made by distilling a mixture of antimony with about twice and a half its weight of corrosive sublimate. The sesqui-chloride passes over and metallic mercury remains in the retort,—or, lastly, by heating powdered *surma* with five times its weight of strong hydro-chloric acid, sulphuretted hydrogen gas escapes, and sesqui-chloride of antimony remains in solution. It is a soft solid at ordinary temperatures, often called from its consistence the "butter" of antimony. It is very caustic and irritating to animal tissues, and is decomposed by water.

Two other chlorides, of little interest, have been described.

The *Oxide of Antimony,* (antimony 1 eq. oxygen 3 eq.) is prepared by pouring the liquid sesqui-chloride into water: a white precipitate falls down, which, when washed with a solution of carbonate of potash, is the pure sesqui-oxide. In this process water is decomposed; its hydrogen with the chlorine forms muriatic acid, its oxygen unites with the antimony.

This oxide is white, with a tinge of yellow, and when heated acquires a full yellow colour, which disappears on cooling. It is fusible in close vessels, and is very volatile. If heated in open vessels it attracts more oxygen and becomes the *Antimonious acid.* The sesqui-oxide is much used in the preparation of one of the most valuable of all medicines, the *tartar-emetic,* a substance described in this section. It forms several salts, most of which are insoluble in water, but are readily dissolved by the tartaric or muriatic acids. From all antimonial solutions the metal is precipitated by sulphuretted hydrogen, as an orange hydrated sesqui-sulphuret, which is soluble in pure potash, and in muriatic acid.

Antimonious acid (antimony 1 eq. oxygen 4 eq.) is prepared by the action of nitric acid on metallic antimony. Hydrated antimonic acid is formed, which, when exposed to a red heat, gives out water and oxygen gas, and is converted into antimonious acid. It is white while cold, yellow when heated, infusible, is not volatile, insoluble in water after being heated to redness, and combines with the alkalies forming salts called *antimonites.*

Antimonic Acid (antimony 1 eq. oxygen 5 eq.) is prepared as stated in the last paragraph.

The *Sulphurets of Antimony* are numerous and important.

The sesqui-sulphuret or *surma,* I have already described. It is formed artificially by passing a current of sulphuretted hydrogen gas through a solution of the tartrate of antimony. An orange red hydrated sesqui-sulphuret subsides, which becomes black when heated, until its water is expelled.

A bi-sulphuret and per-sulphuret have also been formed by the action of sulphuretted hydrogen on the antimonious and antimonic acid.

The oxy-sulphuret of antimony is a compound of 1 eq. of the sesqui-sulphuret and 1 eq. of the oxide. ($\text{Ant. O}_3. + 2$ Ant. Sul. 3.) It exists in the mineral called red antimony ore, and is formed during the pharmaceutical processes for making the glass and crocus of antimony.

PHARMACEUTICAL PREPARATIONS OF ANTIMONY.

The *Glass* of Antimony is thus prepared, according to the process of the London Pharmacopœia.

Strew sulphuret of antimony in coarse powder on a shallow unglazed earthen vessel, and apply a gentle heat so that the sulphuret may be slowly melted. Increase the heat gradually to redness until vapours cease to be given out. Remove the remaining powder, and melt it in a crucible by a very strong heat till it assumes the appearance of melted glass, and then pour it on a brass plate.

In this process part of the sulphur is expelled and its antimony protoxidized, and the oxide with the silica of the dish forms a glass, which, when properly prepared, is in thin, rather transparent, plates of a metallic aspect, hard and brittle, and easily reduced to powder. It is soluble in acids, and in solutions of the bi-tartrate of potash. Glass of lead, which is frequently and fraudulently substituted for that of antimony, is totally insoluble in the last named reagent.

The *Crocus* of Antimony is made by mixing equal parts of the sulphuret and nitre, and throwing the mixture in successive portions into a red-hot crucible, or merely touching it with a red-hot iron. A mixture of the sesqui-sulphuret and protoxide of antimony is formed, and is found in a dark reddish mass; the sulphate of potassa is also generated as a white crust, which must be detached from the crocus. The crocus thus prepared contains about three parts of protoxide and one of sulphuret of antimony.

The *Nitro-muriatic oxide of Antimony* is made by gradually mixing 20 parts of prepared sulphuret of antimony with 100 parts of muriatic and one of nitric acid. The mixture is to be boiled for an hour, and the cooled and filtered liquor thrown into a gallon of water containing three parts of carbonate of soda or potash. The oxide is thrown down as a pale yellow powder, and must be washed repeatedly with warm water. 20 parts of the sulphuret thus treated yield 16.5 of oxide of antimony.

The mode of preparation of the "Butter" or chloride of antimony has been already described.

The formation of the glass, crocus, and oxide may be regarded as merely the preliminary step to the preparation of the

TARTAR-EMETIC, OR TARTRATE OF ANTIMONY AND POTASH.

Dublin process. Take of the nitro-muriatic oxide of antimony 4 parts; bi-tartrate of potash in fine powder 5 parts; distilled water 34 parts: boil for half an hour in a glass vessel, then filter through paper and crystallize by slow cooling. In this process 1 eq. of tartaric acid unites with 1 eq. of oxide of antimony, and a salt composed of 1 eq. of the tartrate of the oxide of antimony, 1 eq. of tartrate of potash, and 2 eq. of water is formed.

London process. Take glass of antimony in very fine powder, and cream of tartar, of each one pound, distilled water one gallon: boil for a quarter of an hour; filter and crystallize by evaporation.

Edinburgh process. Take of *crocus* of antimony in fine powder, and cream of tartar equal weights, and boil the mixture in four times its weight of distilled water for an hour; evaporate and crystallize.

Phillip's process. One hundred parts of metallic antimony in fine powder are to be boiled to dryness in an iron vessel with 200 of sulphuric acid. Wash the residual subsulphate of the oxide of antimony with water, which removes its acids, and boil the oxide with an equal weight of cream of tartar; evaporate and crystallize.

The Dublin process is that which I would recommend for adoption in India, wherever muriatic and nitric acid can be procured, for the preparation of the nitro-muriatic oxide. Where acids are too expensive, the crocus of antimony is the preparation most cheaply and easily manufactured. But the silica combined with the oxide of antimony in the crocus and glass is dissolved also by the cream of tartar, and subsequently impedes the crystallization. To obviate this defect, the entire solution should be evaporated to dryness, which renders the silica quite insoluble, while the tartar emetic can be re-dissolved and crystallized. The powdered mass should never be used without crystallization, the researches of Serullas having shewn that it contains *arsenic*, proceeding from the sulphuret of antimony, but which does not crystallize with the tartar-emetic.

Crystallized tartar-emetic has an astringent metallic taste, reddens litmus paper, is soluble in 15 parts of water at 60°, and in 3 of boiling water. It is decomposed by many substances, such as the pure alkalies and alkaline carbonates which precipitate the oxide of antimony, and by lime water, which gives a mixed deposit of the oxide and the tartrate of lime. The strong acids, such as the sulphuric, nitric and muriatic, throw down from its solutions a mixture of cream of tartar and a sub-salt of the oxide of antimony. Sulphuretted hydrogen and its salts occasion an orange precipitate. Astringent solutions, such as those of gallnuts and cinchona bark, give a white deposit. For this reason a decoction of bark has been recommended as an antidote in cases of poisoning by tartar emetic. Many practitioners have also, in such cases, used with great success, a dilute solution of sulphuret of potash in water.

ANTIMONIAL POWDER.

This popular medicine, termed by the Edinburgh Pharmacopœia the "Oxide of antimony, with phosphate of lime," is identical with the well-known "James's Powder." One pound of sulphuret of antimony is mixed with two pounds of horn-shavings, and calcined in a wide crucible strongly heated. The residuum is powdered, and again heated to whiteness in a covered crucible for two hours. The resulting mass is ground to a very fine powder.

The horns employed consist chiefly of gelatine (see that head) and phosphate of lime. The former is destroyed by the heat, and 36 per 100 of antimonious acid with more than 60 per cent. of phosphate of lime remain.

PHARMACEUTICAL SULPHURETS OF ANTIMONY.

The *prepared* sulphuret is made simply by powdering the common sulphuret in an iron mortar, and by grinding it on a porphyry stone with a little water. More water is then poured on, which is to be decanted off while loaded with the fine powder. This being frequently repeated, very finely divided sulphuret of antimony subsides to the bottom of the vessel, and may be collected and dried for use. This process is called "levigation," and is commonly had recourse to for powdering minerals.

The *precipitated* or *golden sulphuret* is prepared by boiling 1 part of prepared sulphuret of antimony in 18 parts of solution of caustic potash for an hour. The liquor is filtered through cloth, while boiling hot, and eleven parts of dilute sulphuric acid are added. The precipitate must be well washed with hot water and then rubbed into fine powder.

If the solution of sulphuret of antimony in potash be allowed to cool, without the addition of an acid, a fine orange red substance, long called the "Kermes mineral," subsides. If after this has been deposited the acid be added, an additional quantity of a similar substance, of a fine golden colour, is obtained, which is the *precipitate* of the Pharmacopœias. The finest kermes is obtained by boiling for half an hour four parts of sulphuret of antimony in 1000 of water with 90 of crystallized carbonate of soda. The hot solution is filtered into a warm vessel, in order that it may not cool slowly, and after twenty-four hours the deposit is collected on a filter, washed with cold water, and dried at a temperature of 80° F.

There is so much complexity and uncertainty in the theory of this operation, that I forbear from noticing it minutely.

Kermes, according to Berzelius, consists of hydrated sesqui-sulphuret of antimony, with a variable portion of oxide (mechanically mixed) and of potash which cannot be removed by hot water. When the cold solution is acidulated, a mixture of sesqui-sulphuret and sesqui-oxide in variable proportions is precipitated.—The golden sulphuret differs from *kermes* in containing no potash, and having rather more oxide of antimony and some free sulphur.

For the discovery of antimonial compounds in criminal inquiries, the student is referred to the section on the detection of poisons.

CURIOUS COMPOUNDS OF ANTIMONY WITH OTHER METALS.

An alloy of 1 part of antimony with 1000 of gold, renders the latter metal as brittle as glass.

If 70 parts of antimony are fused with 35 of iron, an alloy is produced, which has the singular property of giving off an abundance of sparks when it is filed.

But the most extraordinary of these combustibles is that formed with potassium. When properly prepared it is so inflammable that it ignites gunpowder under water, and has such an attraction for oxygen that it may be substituted for potassium in many experiments. We are indebted to the late distinguished Serullas for several simple processes for the preparation of these alloys.

When metallic antimony in powder is mixed with an equal weight of incinerated cream of tartar and heated strongly, a fused alloy of antimony and potassium is formed. This alloy resembles antimony in appearance, but instantaneously decomposes water, generating hydrogen gas. It takes fire when touched by moistened paper.

If 75 parts of incinerated cream of tartar, 100 of antimony, and 12 of lamp-black be heated to redness in a close crucible and allowed to cool, the resulting alloy spontaneously inflames on opening the crucible, and with such violence that the mixture is projected in a ball of fire like a rocket. Thirty parts of tartar-emetic and one of lamp-black, heated together to redness in a glass tube, and the tube sealed, form a powerful mixture of this description.

SECTION XIX.

BISMUTH AND ITS COMPOUNDS.

Bismuth is found in the native state, or in combination with sulphur, oxygen, arsenic, and other substances. It is a reddish white, brilliant metal, of highly crystalline structure, very brittle when cold, but malleable when warm. Its density is about 10. It fuses at 476°, and is soluble in close vessels. When heated strongly in the open air it burns with the evolution of fumes of the oxide. Its equivalent number is 71 or 213.3, oxygen scale.

The *Protoxide of Bismuth* is prepared by heating the nitrate to redness. It is of a yellow colour, and fusible at a red heat into a liquid, which, when cool, becomes a yellow glass. A *peroxide* of bismuth has also been prepared. The *chloride* of bismuth is made by throwing powdered bismuth into chlorine gas, in which it inflames. The chloride is a soft solid, resembling the butter of antimony.

The *Sub-nitrate of Bismuth*, a very useful remedy, is prepared by dissolving the metal in strong nitric acid, and pouring the saturated solution into water. The sub-nitrate, of a beautifully white colour, subsides. By this method bismuth can be separated and distinguished from all other metals.

The *Sulphuret of Bismuth* is very black, and is at once produced when sulphuretted hydrogen comes in contact with the sub-nitrate.

Two parts of bismuth, one of lead, and one of tin, form a compound so fusible that it melts below the boiling point of water.

SECTION XX.

COPPER AND ITS COMPOUNDS.

The *Copper* of commerce (تامبا *támbá*), is chiefly extracted from the native sulphuret of copper and iron. Some of the sulphur is expelled by heat, which leaves the metals in the state of sub-sulphates. Sand is next added, and the ore again roasted. The iron is oxidized, and unites with the silicic acid, forming a light slag. The residual sulphuret of copper is oxidized by long continued heat, and the oxide finally reduced to the metallic state by fusion with charcoal.

For exact chemical experiments, copper is prepared in the pure state by introducing a piece of zinc or polished iron into a solution of any salt of copper. This metal is quickly deposited, and on washing with water may be considered pure.

The specific gravity of fused copper is 8.96.—melting point 1996. It is more fusible than gold, but less so than silver. It is very ductile, malleable and tenacious; is oxidized at a red heat, but is little acted on by the sulphuric, the vegetable, or muriatic acids, unless the air have free access, when the oxidation proceeds rapidly. Nitric acid acts, however, with great violence on this metal, nitric oxide being disengaged, and a per-nitrate of copper formed. The equivalent number of copper is proved to be 31.7 on the hydrogen, 395.7 on the oxygen scale.

The *Red* or *Din-oxide of Copper* is a crystalline mineral of great beauty, and may be artificially prepared by boiling a so lution of acetate of copper with sugar. The din-oxide subsides as a red powder. It contains 2 eq. of copper and 1 eq. of oxygen. At a red heat it absorbs oxygen, and becomes the peroxide. It dissolves in ammonia, forming, while the air is excluded, a colourless solution, which becomes rapidly blue when exposed to the air, oxygen being absorbed, and the peroxide of copper formed.

The *Black Oxide* (copper 1 eq. oxygen 1 eq.) is prepared by heating copper to redness in the open air, by precipitating the salts of copper by potassa, or by heating the nitrate of copper to redness. When heated to redness, this oxide undergoes no change, unless combustible matter be present, when it is quickly reduced to the metallic state. It is insoluble in water, and combines with the acids, forming salts of a green or blue colour. It is also soluble in ammonia, forming a solution of a fine blue colour.

The salts of copper are easily recognized, being precipitated blue by the alkalies (the hydrated oxide), black by the sulphuretted hydrogen, and chesnut-brown by the ferro-cyanuret of potassium. Albumen, such as the white of eggs, causes a yellow precipitate, a compound of oxide of copper, and albumen, devoid of any poisonous properties. The whites of eggs are hence an antidote to the soluble copper poisons.

The *Di-chloride* is formed by throwing copper filings into chlorine gas, in which the metal inflames spontaneously, or by heating copper filings with twice their weight of corrosive sublimate. This di-chloride varies in colour according to the mode by which it is prepared. It is fusible at a heat below redness, insoluble in water, is dissolved by muriatic acid, and precipitated from it by dilution with water. It attracts oxygen from the air, forming a green oxy-chloride, identical with that deposited on the copper sheathing of ships when long exposed to the action of sea water.

The *Chloride of Copper* is made by dissolving protoxide of copper in muriatic acid, evaporating, and crystallizing. It is deliquescent in the air, and soluble in alcohol.

The *Di-sulphuret of Copper* is formed artificially by heating copper filings with one-third of their weight of sulphur. Combustion takes place by the application of a very gentle heat, and the mixture undergoes vivid ignition.

SALTS OF COPPER.

The *Sulphate of Copper* (protoxide) contains 1 eq. acid and 1 eq. oxide of copper. It is sold in the Indian bazars under the name of *tutiyá*, توتيا, being imported chiefly from Pegue. Considerable quantities are formed during the operations at the Mint, and are sold at a cheap price in the Calcutta market. In Europe it is generally made on the large scale, for the use of the dyers and ink-makers, by evaporating the waters of copper mines, or by dissolving the oxide or native carbonate in dilute sulphuric acid. This salt is of a fine blue colour, soluble in four parts of cold and two of boiling water.

The *Sulphate of Copper and Ammonia*, the *Ammoniuret of Copper* of the Pharmacopœias, is made by dropping ammonia into a solution of the sulphate, until the oxide thrown down is nearly redissolved. A dark blue solution is produced, from which crystals are obtained on slow evaporation and the addition of alcohol. The same compound may be made by rubbing 2 parts of sulphate of copper in a mortar with 3 parts of carbonate of ammonia. The mixture acquires a deep blue colour; carbonic acid is disengaged, and the mass becomes fluid, owing to the extrication of the water of crystallization of the sulphate of copper.

The *Nitrate of Copper* is prepared by the action of nitric acid on copper, in the manner described under the head of nitric oxide. When evaporated to dryness a crystalline, blue, deliquescent salt is obtained.

If a few fragments of this nitrate be wrapped up quickly in a piece of moistened tin-foil, the tin is oxidized with such rapidity that intense heat is produced, and the metal takes fire.

The *Peroxide of Copper*, so much used in the analysis of organic substances, is best prepared by heating this nitrate to redness.

The *Carbonate of Copper* is prepared by adding the carbonate of potash or soda to a solution of the sulphate of copper. It forms the green paint called *Verditer*, and the mineral, called blue copper ore. The beautiful mineral "Malachite" is a di-carbonate of copper. The carbonate of copper abounds at Nellore, in Southern India.

Acetates of Copper. The neutral acetate may be formed by dissolving protoxide of copper or common *verdigris* by acetic acid, or by decomposing the sulphate of copper by the acetate of lead. Sulphate of lead is precipitated, and acetate of copper crystallizes from the solution in dark-green octohedra, soluble in 20 times their weight of cold, 5 of boiling water, and in 14 of boiling alcohol.

The paint called *verdigris* is prepared in large quantities in France, specially near Montpelier, by covering sheets of copper with grape skins. These containing some sugar furnish acetic acid by fermentation, and in a few weeks the plates are incrusted with a mixture of the neutral acetate and sub-acetate of copper. In England copper sheets are covered with cloths steeped in wood vinegar, by which process a better article is said to be obtained.

The most important circumstances connected with the subject of poisoning by copper, and with the mode of detecting its preparations, are attended to in a separate section.

SECTION XXI.

LEAD AND ITS COMPOUNDS.

Lead (سيسا *sísá,*) and several of its compoun dsare well known, and extensively produced in the East. The lead of commerce is generally extracted from the sulphuret called *Galena,* which is broken to coarse powder, oxidized by exposure to heat in a reverberatory furnace, and finally sulphurous acid is disengaged, and metallic lead subsides. The slag on the surface of the mass consists chiefly of sulphate of lead. This is mixed with quicklime, and again heated with fresh *galena.* The oxide of lead set free with the sulphuret of lead forms sulphurous acid and metallic lead, as in the first decomposition.

Lead is of a blueish grey colour, strong lustre when recently cut, but tarnishes on exposure to the air, becoming covered with carbonate of the protoxide of lead. Specific gravity 11,44. It is soft and flexible, very malleable and ductile, but little tenacious, and destitute of elasticity. It fuses at 612°, but may be heated to whiteness without undergoing sublimation. The equivalent of lead is 103.7, or 1294.5 on the oxygen scale.

When fused in open vessels, a crust of the protoxide forms on its surface. If immersed in water and exposed to the air, it oxidizes rapidly, and carbonate of lead is formed. It is a very curious fact, for the knowledge of which we are mainly indebted to Dr. Christison, that the presence of saline matter in water retards the oxidation of lead; and some neutral salts in extremely minute quantities completely prevent that action. If the salt is one the acid of which forms an insoluble compound with the oxide, (such as a phosphate,) 1-30,000 part of the salt will effectually prevent the corrosion of the metal. The practical inferences from these facts are very important. Many preparations of lead are highly poisonous, and numerous fatal accidents have occurred by the water being kept in leaden cisterns. But when the water either naturally contains, or is artificially mixed with the most trifling quantity of the sulphate or phosphate of soda, leaden reservoirs may be used with perfect safety.

Nitric acid oxidizes and dissolves lead with great rapidity. Sulphuric acid does not act on it while cold, and but slowly when boiling. The muriatic and vegetable acids do not affect it directly, though they facilitate its oxidation through the agency of the atmosphere.

The *Protoxide* of *Lead* (*murdár sang*, مُردار سنگ) is prepared by collecting the grey film which forms on the surface of melted lead, and heating it in the open air until it becomes yellow. In this state it is called *Massicot* in commerce, and when partially fused it receives the name of *Litharge.* Or in a purer state it may be made by adding ammonia to a solution of the nitrate of lead, and heating the precipitate to redness.

This oxide is red while hot, yellow on cooling, insoluble in water, fusible at a bright red heat, but not volatilized. Its sp. gr. is 9.42. When fused its texture is flaky, its consistence tough. It is readily reduced to the metallic state by heat and combustible matters. It is the basis of all the salts of lead, from which it is precipitated as a white hydrate by alkalies; as a white carbonate by alkaline carbonates; as a white sulphate by soluble sulphates; as a black sulphuret by sulphuretted hydrogen or the hydro-sulphurets of the alkalies or earths; and, lastly, as a yellow ioduret by a solution of the hydriodate of potash. The salts of lead are decomposed by zinc or iron, the lead being separated in the metallic state. To shew this curious fact, dissolve 1 part of acetate of lead in 24 of water, and suspend a piece of zinc in the solution by a thread. The lead is deposited upon the zinc in a beautiful tree-shaped mass.

The protoxide of lead when heated with earthy substances forms a kind of glass, and is much employed in this way for glazing earthen vessels. Litharge, too, is much used in the manufacture of flint glass, which it renders very fusible and transparent.

The *Red Oxide*, or *Minium (sendur,* سیندر) (lead 3. ox. 4 eq.1.) is manufactured and sold in great quantities as a paint, and for glass-making. It is not a definite compound, being composed of variable proportions of the protoxide and peroxide. Heated to redness, or boiled with sulphuric acid, it evolves oxygen gas. Boiled with muriatic acid, chlorine is obtained. With nitric acid, a solution of proto-nitrate of lead is formed, and peroxide of lead subsides. Minium is prepared on the large scale by exposing the common oxide to heat and air at a temperature of about 700° in a reverberatory furnace.

The *Peroxide* (lead 1 eq. oxygen 2 eq.) may be made by the action of nitric acid on lead, as just described—or by transmitting a current of chlorine gas through a solution of the acetate of the protoxide of lead. Peroxide of lead and chloride of lead are formed, the latter of which is removed by washing with warm water. The peroxide is of a purplish colour, insoluble in water, yields oxygen with nitric or sulphuric acid, chlorine with muriatic acid, and oxygen gas when heated to redness.

The protoxide of lead forms with the alkalies and earths a curious series of compounds called *plombates*. Those of potash and soda are very soluble, that of lime slightly soluble in water. These plombates are used for dyeing the hair black : the alkali removes the oily matter of the hair, and the sulphur which the hair contains forms a black sulphuret with the lead. A mixture of 2 parts of protoxide of lead and 8 parts of caustic lime, made into a paste with water, will effect this change in a few hours.

The *Peroxide of Lead* is decomposed by ammonia, and the singular result is the production of water and *nitrate of lead*. Sulphurous acid converts it into sulphate of protoxide of lead so suddenly that ignition often ensues, and thus in the analysis of mixed gases the sulphurous acid gas can be separated from the carbonic acid. Mixed with one-sixth of its weight of sulphur and well dried, it forms a powder which takes fire without explosion on being strongly rubbed together, sulphuret of lead being formed, and sulphurous acid disengaged.

The *Red Lead* of commerce is frequently adulterated with red oxide of iron and brick dust. These frauds are easily detected. When pure Minium is heated it becomes yellow, the adulterated article retains its colour. Strong muriatic acid dissolves the oxides of lead and iron, and leaves the brick dust. The muriatic solution is evaporated to dryness and treated by alcohol, which dissolves the chloride of iron and leaves the chloride of lead.

Chloride of Lead, or Horn Lead, is made by exposing sheet lead to the action of chlorine gas, or by mixing saturated solutions of acetate or nitrate of lead and common salt. The chloride is precipitated, and may be redissolved by hot water, from which it is deposited on cooling in small needle-shaped white crystals. It is very fusible, and on cooling becomes a semi-transparent horn-like mass.

There is an oxy-chloride of lead, composed of oxide and chloride in variable proportions, called "mineral, patent, or Turner's yellow." It is of a fine golden colour, extremely fusible, and crystallizes on cooling. It is prepared by making a paste of 7 parts of litharge, 1 of common salt, and 4 of water. The mixture is well stirred, and more water added as it thickens. It becomes white gradually, and in 24 hours caustic soda is formed in solution, and the oxychloride of lead remains as a white powder, which is fused in a close furnace, and cast in iron moulds. In this state it is much used in painting.

The *Ioduret of Lead,* a remedy of much value in scrofula and syphilis, is prepared by adding a solution of hydriodate of potash to a solution of the acetate of lead. The ioduret of lead is precipitated as a brilliant yellow powder, which is soluble in boiling water, crystallizing as it cools in minute flakes like particles of gold leaf.

The *Sulphuret of Lead* occurs naturally in cubic crystals (black ore of lead or galena), and artificially is made by passing sulphuretted hydrogen gas through any lead solution, or by fusing together a mixture of sulphur and lead.

SALTS OF LEAD.

Carbonate of Protoxide of Lead, the white lead of painters, Ceruse, (*sufedá*, سفیدا) occurs in the mineral state in white prismatic crystals, and is made artificially by acting on thin sheet lead with the vapours of vinegar; protoxide of lead is formed, and unites with the carbonic acid of the air. It is a white pulverulent substance, the most poisonous of the lead preparations.

The *Acetates of Lead* are three. The neutral acetate or "sugar of lead," is made by dissolving the carbonate or litharge in distilled vinegar. The solution is sweet and astringent, and crystallizes in needles. The crystals are soluble in 4 parts of cold water. If the water contains carbonic acid or carbonates, the solution is milky, but is rendered clear by the addition of a little acetic acid. This acetate is extensively used in medicine, in the arts, and in analytic chemistry, and is indeed one of the most useful of all the metallic compounds.

The *Sub-Acetate* is made by boiling 1 part of the neutral acetate, and 2 parts of fused litharge in 25 parts of water. It is very soluble, has an alkaline reaction on test paper, and is decomposed by a current of carbonic acid. It is composed of 1 eq. acetic acid, and 3 eq. of protoxide of lead.

The *Di-Acetate* is formed by boiling litharge and the neutral acetate in suitable proportions.

The *Nitrate of Lead* has been already described. The other salts do not require especial notice.

SECTION XXII.

METALS OF THE SECOND CLASS, HITHERTO UNAPPLIED TO USEFUL PURPOSES.

The remaining metals of this class are devoid of all interest except what attaches to their elementary nature, having as yet been found in quantities too minute for use, or on trial having proved useless in medicine or the arts: I therefore give but a conspectus of their distinguishing properties.

Molybdenum is a brittle white metal, very infusible; specific gravity 8.61, combining equivalent 47.7. It is prepared from the sulphuret, a mineral resembling graphite, found chiefly in Transylvania and in Ceylon. The oxides of this metal are three—the protoxide, black—the bin-oxide, brown. The third possesses acid properties, and is called the molybdic acid. Its colour is white, and its salts are colourless. This acid is soluble in 570 times its weight of water.

Tungsten is obtained from the mineral *Wolfram*, a tungstate of the oxides of iron and manganese. It is a greyish white metal, very hard and infusible; specific gravity 17.4; equivalent 99.7. It forms two oxides. The protoxide is dark brown—it does not unite with acids, and when heated ignites, combines with another equivalent of oxygen, and forms the yellow tungstic acid. This acid is insoluble in water, and forms salts called tungstates.

Columbium, obtained from the very rare mineral tantalite is of an iron-grey colour and very infusible. Its combining equivalent is 185°. It forms two oxides, the protoxide, dark grey, the peroxide white, and possessed of acid properties, and termed the Columbic acid.

Uranium is obtained from the mineral called *pitch-blende*, a compound of oxides of uranium and iron. The metal has only been prepared once. Its colour is reddish brown, its equivalent 217. The protoxide is green, and with acids forms green salts. The peroxide is orange, and its salts of the same tint. Both these oxides have been employed to give their corresponding colours to porcelain.

Cerium was obtained from the minerals *cerite* and *allanite*. Its properties are nearly unknown. It is described by Vauquelin as a white brittle metal. Its combining equivalent is 46. Its protoxide is white, its peroxide a fawn-red.

Lanthanum, lately discovered by Mosander, is always associated with Cerium. Its history is as yet obscure.

Titanium is an ingredent in an iron ore, very abundant in Madras, and which has been recently described by Dr. Benza. It also occurs in some varieties of mica, and its oxide has been found in Hessian and Cornish crucibles. Titanium has been found in the metallic state in some iron smelting furnaces. Its colour resembles copper. Specific gravity 5; very hard and infusible, combining equivalent 24.3. The protoxide is purple, the peroxide or titanic acid is white. Its soluble salts acquire an orange-red colour, when tincture of gall-nuts is poured on them; and when a rod of zinc is suspended in their solutions, a purple powder, the protoxide is thrown down.

Tellurium is very rare, and has only been found in the Transylvanian gold mines, where it is associated with gold and silver. Its colour is white, texture brittle, density 6.25. Its equivalent number 64.2. It forms two acid compounds with oxygen,—the *tellurous*, a white granular powder; the *telluric*, lemon-coloured when anhydrous, and transparent and colourless when combined with water of crystallization. Tellurium forms with hydrogen a gaseous compound, the hydrotelluric acid, which in many of its properties resembles sulphuretted hydrogen.

The equivalents above quoted are all on the hydrogen scale.

THE METALS.

CLASS II.—ORDER III.

METALS THE OXIDES OF WHICH LOSE THEIR OXYGEN AT A RED HEAT.

SECTION XXIII.

MERCURY AND ITS COMPOUNDS.

Mercury or *Quicksilver (párá* پارا Hind. *símáb* سيماب *Pers. rasa* रस Sanskrit) is a metal of great importance in the arts and medicine. It occurs naturally in the elementary state or combined with sulphur and minute quantities of other metals. The sulphuret has been found in Thibet and Nipal, and is imported into India in considerable quantities from the Straits and Japan. The most remarkable mines of mercury, however, are those of Idria in Germany, and Almaden near Cordova in Spain.

The bulk of the metal found in commerce is prepared from the native sulphuret, natural cinnabar, a mineral described in the sequel of this section. The sulphuret is heated with lime or iron filings. Sulphuret of lime or iron is formed and the mercury volatilized. The steps in this process may be distinctly seen by heating together a mixture of 100 grains of cinnabar and lime in a glass tube or small flask. The mercury thus prepared on the large scale is seldom perfectly pure, containing variable proportions of zinc, lead, and tin. To purify the metal for the arts it is mixed with iron filings and distilled from an iron retort. The admixture of iron in this case only serves to diminish the violence of the boiling, an object which it accomplishes in the same mode as pieces of platinum foil or glass, moderate the ebullition of sulphuric acid. Even after the distillation, the mercury of commerce contains impurities which render it unfit for pharmaceutical purposes. To render it perfectly clean, it is agitated with cold concentrated sulphuric acid, which does not affect the mercury, but oxidizes and separates the associated metals in the form of a white powder. The metal is next washed with water, dried, and pressed through chamois leather or fine cloth.

Mercury is a brilliant, white metal, fluid at ordinary temperatures, but solid when exposed to the intense cold of 39° below the zero of Fahrenheit. The specific gravity of frozen mercury is 15.61, of the fluid metal 13.54.—At 662° it boils, and condenses on cool surfaces in minute globules; when perfectly pure it does not attract oxygen from the air until strongly heated, but the most trifling quantity of any other metal causes it to oxidize with much rapidity. From the film which thus forms, the metal is most readily freed by being filtered through a cone of thick paper, with a minute aperture at the point.

Pure mercury is recognized by its brilliancy, by its dividing when spilled into a multitude of perfectly round globules, which again coalesce when brought together; by its moving freely on sloped surfaces without forming a tail or film, and by its being totally volatilized without residue when heated in a glass tube below redness.

When mercury is heated for several days in a very wide and shallow glass vessel with a long narrow neck, in contact with air or oxygen gas, the metal is slowly oxidized and the red peroxide is formed. No acid but the sulphuric and nitric effect the oxidation of the metal, and the reaction which takes place in these instances is described in treating of the corresponding salts.

Dr. Turner's recent researches (Philosophical Transactions, 1833, Part iv.), have established decisively that the equivalent number of mercury is 202, not 200, as it has long been estimated.

In still later works I find the equivalent stated at 101.4, the red oxide called the protoxide, &c. I do not consider it expedient at present to adopt, on merely theoretical grounds, changes likely to lead to confusion and danger in the medicinal use of the numerous preparations of this metal.

OXIDES OF MERCURY.

The *Protoxide*, (mercury 202, 1 eq. oxygen 1 eq. 8), a black insoluble powder, is prepared by mixing the protochloride (calomel) with pure potassa in a mortar, washing the black product with cold water, and allowing it to dry in a dark place. It is a difficult process, because the protoxide when exposed to heat, or even to light, changes into the peroxide and metallic mercury. This oxide forms several important salts, all of which give a black precipitate with alkalies and lime-water—a white precipitate with alkaline carbonates. With muriatic acid or its soluble salts they form calomel, the proto-chloride; and by sulphuretted hydrogen the black sulphuret of mercury is thrown down.

By long trituration with viscid or greasy matters, or inert powders, such as lard, chalk, manna, magnesia, &c., mercury is gradually oxidized in the first degree. Several preparations of this kind are described in pharmaceutical works, but as they are only mechanical compounds, they do not fall within the objects of this volume.

The *Peroxide* (mercury 1 eq. 202, oxygen 2 eq. 16) is made by dissolving 3 parts of mercury in 2 of strong nitric acid and 2 of water, and heating the per-nitrate of mercury thus formed in a porcelain capsule until all its acid is expelled. A crystalline scaly mass is obtained, which is black while heated, but assumes a lively red colour on cooling. This oxide is slightly soluble in water. When heated to low redness it evolves 2 eq. of oxygen, and metallic mercury remains.

It is an acrid, poisonous and caustic preparation, used in surgical practice as an external application. With acids it forms several salts, which give an orange yellow precipitate with potash, soda, and lime, and a white precipitate with ammonia. These salts are decomposed by copper, and the mercury deposited. Proto-chloride of tin also reduces the metal in its simple state.

CHLORIDES OF MERCURY.

The *Proto-chloride* (Calomel. Mild muriate or sub-muriate of mercury. Sub-murias hydrargyri)—Mercury 1 eq. 202, Chlorine 1 eq. 35.42, is formed by several processes. Cold mercury unites with chlorine gas, to form this compound, or if mercury be mixed with the bi-chloride (corrosive sublimate) and sublimed—or proto-nitrate of mercury be precipitated by muriate of soda, the same result is obtained.

To prepare calomel for medicinal use, Henry's process is by far the best. He uses two retorts, iron or earthen ware, the necks of which are introduced into the opposite orifices of a glass or earthen vessel with three apertures, the third being intended to receive a safety tube. One retort has a very stout wide neck, and its body is so placed in a furnace that it can be heated to bright redness. Into this retort is introduced a mixture of six parts of persulphate of mercury, four parts of metallic mercury, and three parts of chloride of sodium, (sea-salt.) The opposite retort contains water. On heating the retort containing the mixture, white vapours soon appear. The water is then boiled, and the vapours of calomel are condensed in a fine white impalpable powder by the steam. When the vapours cease to appear, the powder is well washed with water, filtered, sifted, and dried.

The theory of this process shall be described as we proceed. It is sufficient to state now that the sulphuric acid of the sulphate of mercury decomposes the chloride of sodium,—that bi-chloride of mercury is first produced, which divides its chlorine with the metallic mercury, and the proto chloride, calomel, is formed. The washing is practised for the removal of any bi-chloride (corrosive sublimate) accidentally present.

Sublimed Calomel is prepared from the materials above specified by heating them, without the contact of steam, in a proper subliming apparatus. It occurs in crystalline, nearly transparent cakes, specific gravity 7.2; it is volatile, yellow while warm, tasteless, and insoluble in water; turned black by alkalies and lime water.

This compound is so extensively and sometimes so beneficially employed in medicine, that its properties should be thoroughly studied. It is liable to contain corrosive sublimate when carelessly prepared; and as calomel thus contaminated may occasion irreparable mischief, the detection of the corrosive sublimate is a matter of much practical importance. Suspected calomel should be well washed with distilled water, the washings evaporated nearly to dryness, and lime water added to the residue. If any corrosive sublimate is present, lime water gives a red precipitate, which is to be dried and weighed. 218 parts, or 1 eq. of this precipitate, correspond to 272 parts, 1 eq. of corrosive sublimate. Within the last few years calomel has also been extensively adulterated with powdered sulphate of baryta. This iniquitous fraud is detected by heating a given weight of the calomel to redness on a thin slip of talc or platinum foil, till the calomel is sublimed; the sulphate of baryta remains as a white powder, which does not change colour on being mixed with alkalies or lime water, and is insoluble in strong nitric acid.

The Bi-chloride of Mercury, (mercury 1 eq. 202, chlorine 2 eq. 70.84,) like that just described, has received a variety of names according to the progress of chemical science. It is called *corrosive sublimate* from its poisonous properties, and *muriate* or *per-muriate of mercury* from its supposed chemical composition. The *bi-chloride*, however, is the correct name, to which, to prevent accidents, that of corrosive sublimate should be appended.

Corrosive sublimate is formed by introducing hot mercury into chlorine gas; the mercury inflames, and the bi-chloride is formed. Or the vapour of boiling mercury may be led into a vessel continually supplied with chlorine; corrosive sublimate is formed and condensed without being inflamed. On the large scale it is generally manufactured by subliming in glass, earthen, or iron vessels, a mixture of 1 eq. (or 298 parts) of the bi-sulphate of the per-oxide of mercury, (see that head) and 2 eq. (or 117.44 parts) of chloride of sodium, common salt. I subjoin the diagram by which Dr. Turner illustrates the double decomposition which occurs. Thus on mixture there are---

Bi-Sulphate of Mercury,	1 eq.	*Chloride of Sodium,*	2 eq.
Sulphuric acid,..	80.2 or 2 eq.	Chlorine,......	70.84 or 2 eq.
Per-ox. of mer. ..	218—or 1 eq.	Sodium, ...	46.6 or 2 eq.
	298.2		117.44

On sublimation these produce by mutual interchange of elements—

Bi-chloride of Mercury,	1 eq.	*Sulphate of Soda,*	2 eq.
Mercury, ...	202 or 1 eq.	Sulphuric acid,	80.2. or 2 eq.
Chlorine,........	70.84 or 2 eq.	Soda,..........	62.6 or 2 eq.
	272.84		142.8

This may be regarded as the result of a reaction between 1 eq. of peroxide of mercury, and 2 eq. of chloride of sodium; 2 eq. of protroxide of sodium, and 1 eq. of bi-chloride of mercury being formed.

Corrosive sublimate obtained by the last process is in crystalline, semi-transparent, colourless cakes, specific gravity 5.2; of acrid, burning, nauseous taste; very fusible and volatillized by heat. It is soluble in 20 times its weight of cold, and twice its weight of boiling water; also soluble in alcohol, and remarkably so in sulphuric ether. From all these solutions it is deposited by evaporation in slender prismatic crystals. Solutions of corrosive sublimate are decomposed by many vegetable and animal substances, especially albumen, a white precipitate being formed, composed of the proto-chloride (calomel) and albumen.

For the detection of corrosive sublimate in cases of poisoning, the reader is referred to the section on that subject.

A curious and most useful application of this substance has recently been discovered and patented by Mr. Kyan. I allude to the preservation of timber, cordage, sail cloth, and other fabrics from decay by mould, or the ravages of insects. The article is steeped in a tank, containing a solution of corrosive sublimate in water, for a period of a month or longer. The albuminous and soluble parts of the tissue gradually decompose the corrosive sublimate, and a compound of these organic principles and calomel is formed. This substance is completely insoluble in water, and cannot be volatilized by a heat below that which would destroy the wood or similar fabric. Hence, while the preservative influence is complete, as far as regards spontaneous decomposition, the timber or canvas so prepared cannot exert any injurious influence on persons constantly in its vicinity. The evidence in favour of the invention, as far as regards the attacks of insects, is not so satisfactory, but there are many facts which tend to shew that even the white ant will not venture on a repast from materials thus seasoned.

The corrosive sublimate may be prepared very economically in India, by adopting the Dutch process of subliming a mixture of dried sulphate of iron (*híra-kasís,*) nitrate of potash, muriate of soda, and quicksilver. The sublimation may be effected in common vessels of Kedgeree-ware, made in the shape of the Zara Maraschino bottles; the bottle should be half filled with the mixture, and heated in a sand bath. The mouths of the bottles should be loosely stoppered, and the upper part kept cool by moistened cloths. A row of any number of bottles may be placed over a suitable fire-place, which should be so arranged that a constant draught of air can be kept up through the apartment; other wise the vapours of the corrosive sublimate, which must escape more or less, may occasion serious mischief to the workmen and visitors of the place.

A still easier and a perfectly safe process is to prepare the red oxide of mercury by nitric acid; dissolve 1 equivalent of this in 2 eq. of muriatic acid and crystallize.

For additional details relative to the preparation of corrosive sublimate and calomel, reference must be made to the description of the sulphates and nitrates of mercury.

IODURETS OF MERCURY.

Of these there are three, the proto, sesqui, and bin-iodurets, of which the first and last are valuable medicinal agents.

The *proto-ioduret* is made by mixing a solution of hydriodate of potash and *proto*-nitrate of mercury. It is a green insoluble powder.

The *Sesqui-ioduret* falls as a yellow powder when a solution of the ioduret of potassium is added to a solution of the mixed proto-nitrate and per-nitrate of mercury.

The *Bin-ioduret* is made by mixing a solution of the pernitrate, or of corrosive sublimate, with a solution of ioduret of potassium. A fine red precipitate of vermillion tint is formed. This precipitate is very soluble in an excess either of the ioduret of potassium or corrosive sublimate. If dissolved in a hot solution of per-nitrate of mercury, it crystallizes in beautiful red scales as the solution cools.

This compound is fusible at 400°, then sublimes and concretes in yellow scales, which retain their colour on cooling if the subliming vessel be kept still; but on disturbing or touching the crystals the rich red colour rapidly returns.

SULPHURETS OF MERCURY.

The black *Proto-sulphuret* is made by passing sulphuretted hydrogen gas through a dilute solution of proto-nitrate or proto-acetate of mercury, or through water in which calomel is suspended. By heat this compound is changed into the bi-sulphuret and metallic mercury.

The *Bi-sulphuret* (mercury 1 eq. 202, sulphur 1 eq. 32) occurs in the native state in several varieties either massive or crystalline. In the bazars it is sold in abundance, and will afford the student the best material for experiments on all mercurial compounds. It is the *durdár* دردار of the Hindus; in Sanskrit "*Inghúlam.*" It is made by fusing sulphur with about six times its weight of mercury, and subliming in close vessels. When reduced to powder, levigated and kept for some weeks under water, it acquires a remarkably rich tint, and in this state constitutes the *vermillion* of commerce.

Cinnabar is insoluble in alkalies and acids, with the exception of the nitro-muriatic.

SULPHATES OF MERCURY.

The *Proto-sulphate of Mercury* (protoxide mercury 210, 1 eq., sulphuric acid 40, 1 eq.) is made by heating mercury in sulphuric acid so as to cause gentle effervescence. A white compound is gradually formed. It is crystalline, deliquescent in the air, gives a black precipitate (protoxide) with lime-water and a white precipitate (calomel) with a solution of common salt, and is not changed in colour by the addition of water.

The *Bi-persulphate* (sulphuric acid 2 eq. 80, peroxide mercury 1 eq. 218) is made by boiling together to dryness 2 parts of mercury and 3 parts of concentrated sulphuric acid. Sulphurous acid is evolved and a white saline mass is left. This is a very tedious, troublesome, and somewhat uncertain process, but has been much improved by Dr. Barker of Dublin, who uses equal weights of sulphuric acid and mercury, and one-sixth of nitric acid. The addition of the nitric acid economizes three-fourths of the time, fuel, and labour employed, and gives a whiter product, composed of bi-sulphate of the *per*-oxide alone. This is a point of some consequence, because this sulphate is made only as a preliminary step in the manufacture of corrosive sublimate. If the oxidation be incomplete—that is, if a sulphate of the *protoxide* instead of the peroxide be formed—it is obvious that when mixed with chloride of sodium, the *protoxide* can only decompose 1 eq. of the chloride, set *one* eq. of chlorine free, and thus produce the proto-chloride of mercury or calomel;—while, on the other hand, 1 eq. of the *per*-oxide of mercury decomposes 2 eq. of the chloride, liberates 2 eq. of chlorine, and thus produces the bi-chloride, or corrosive sublimate.

The Bi-persulphate is known to be sufficiently oxidized when it is totally dissolved when thrown into a solution of common salt, and when it gives a clear red colour with lime-water.

When this salt is thrown into hot water it loses 1 eq. of its sulphuric acid, which unites with the water, and a neutral per-sulphate of mercury (sulphuric acid 1 eq., per-oxide mercury 1 eq.) is thrown down. This is a fine yellow powder, insoluble in water. It was formerly called Turpeth mineral, and much used in medicine. It is a violent emetic, and now never employed. The water employed in the precipitation holds in solution, along with sulphuric acid, a small quantity of the persulphate, which it yields on evaporation in minute crystals.

THE NITRATES OF MERCURY.

The *Proto-nitrate* is made by acting on cold metallic mercury with one part of nitric acid and 4 parts of water, until the acid is saturated. The solution is allowed to evaporate spontaneously, when fine white crystals are formed.

The solution of this salt yields a black precipitate with the alkalies and lime water, and a copious white precipitate of calomel (proto-chloride) with a solution of sea-salt. 1 eq. of protoxide decomposing 1 eq. of chloride of sodium, liberating 1 eq. of chlorine, which with 1 eq. of mercury forms calomel.

The *Per-nitrate* is formed by heating mercury in an excess of strong nitric acid. Nitric oxide is rapidly disengaged and fine crystals of the white per-nitrate are deposited. When these crystals are thrown into hot water, a yellow sub-salt is thrown down, composed of 1 eq. nitric acid, and 2 eq. of per-oxide of mercury. Solutions of the pernitrate give orange precipitates with potash, soda, and lime, white with ammonia, and fine red with the ioduret of potassium. When dried and heated, half the nitric acid is first expelled and the yellow di-nitrate formed. Continuing the heat, nitrous oxide escapes, and peroxide of mercury remains, of a black colour while hot, but rapidly reddening as it cools.

The *Proto-acetate* is made by adding to a hot solution of acetate of potash a solution of the proto-nitrate of mercury. The liquid is quickly filtered, and on cooling the proto-acetate of mercury is deposited in soft talc-like crystals. This was once a remedy of high repute, but is now very seldom administered.

WHITE PRECIPITATED MERCURY.

This salt is one of the compounds of mercury, first described by chemical writers; corrosive sublimate is very soluble in solutions of muriate of ammonia, and if potash or soda be added, this white precipitate occurs. It is described by Duncan as a sub-muriate of mercury and ammonia. Dr. Kane's researches have shewn it to be a chloramide of mercury, composed of mercury, chlorine, and amidogen (nitr. 1. hyd. 2 eq.)

INDIAN MERCURIAL PREPARATIONS.

Several preparations of mercury have been described by the Sanskrit and Tamul writers, especially in the "*Purana*

Sastram," a work on materia medica and religious observances. The processes I have examined generally lead to the production of a mixture of calomel and corrosive sublimate, and accordingly the analysis of all the bazar preparations I can collect, shews their composition to be a mixture of varying proportions of these substances.

The *Raskarpúr* is generally considered to be corrosive sublimate, but on analysis I find that it is usually *calomel.* Once, however, I met a specimen which was corrosive sublimate of the finest kind. The cause of the uncertainty is to be traced in the different proportions of the ingredients recommended by different native writers, and which of course must lead to the results described.

I insert from Dr. Ainslie's work, an account of the preparation of the *Rassapuspum* and the *Shavirum,* a compound similar to the *Raskarpúr.*

RASSAPUSPUM.

" This is a sort of muriate of mercury, in great repute amongst the Tamuls, and which appears to be administered by them in larger doses than any of the other preparations of this metal. The following is taken from '*Aghastier Vӯtiah Anyouroo*:'—'Twelve pagodas weight of sulphur is to be put into an earthen pot, and fused over a slow, but strong fire: when in a state of fusion, eighty pagodas weight of quicksilver must be added to it, and kept gently stirred till the whole is reduced to a black powder: another pot is then to be taken, and filled half full of small pieces of brick, over which is to be laid one measure of common salt: on the top of this salt is to be put the black powder just mentioned; covering the whole with another earthen vessel; the part where the mouths of the two vessels meet is to be well coated over with soft clay, and afterwards bound round with five piles of coarse cloth; the pots, thus joined, are then to be placed on a strong fire, and there to be kept for twelve hours; after which time they are to be taken off and left to cool, when the *rassapuspum* will be found collected in the uppermost.' "

Here we have a sulphuret of silver first formed, which decomposes the chloride of sodium and forms bi-chloride of mercury. It is very remarkable that the quantities employed are nearly in strict accordance with the indications of the atomic doctrine. Thus the atomic weight of 2 eq. of sulphur is 32, of mercury 202, or nearly in the same proportion as 12 of sulphur and 80 of mercury employed by the Indian druggist. The 2 eq. of sulphur again decompose 2 eq. of salt, liberating 2 of chlorine, which, with the mercury, produces the bi-chloride or corrosive sublimate. But it generally happens that through defective manipulation a mixture of calomel and the bi-chloride is formed.

The next extract is still more interesting:

SHAVIRUM.

"This strange compound is administered by the Tamuls in very small quantities; and well it ought to be, as it is evidently a harsh, uncertain, and dangerous preparation. The following process for making it is taken from the '*Púrána Sastrum*;'—' First, make rassapuspum, of the strength that will be formed by using the proportions of sixteen pagodas weight of sulphur, eighty pagodas weight of quicksilver, and half a measure of common salt. Then, to eighty pagodas weight of this rassapuspum, add the same quantity of roasted salt: to these, again, are to be added the following substances: forty pagodas weight of roasted túrushú (sulphate of copper), twenty pagodas weight of paddicarum (alum), twenty pagodas weight of pottle úppú (nitre), twenty pagodas weight of púnhír (a sort of alkaline earth), ten pagodas weight of anna baydie (sulphas ferri), and five pagodas weight of navacharum (sal ammoniac). All these to be well rubbed together till formed into an uniform powder, which is to be put into a cooppie sufficiently large to hold the whole in one-half of it; after which, it is to be well coated round with clay, and set over an oven like the shadilingum, where it is to be kept for thirty-six hours, taking care that the fire, though slow, is strong; the cooppie is then to be broken, and in the mouth of it will be found the shavirum, in a lump.' "

In this process, the mixed chlorides of mercury, above described, are treated so as to combine them with still more chlorine, and bring all to the state of the bi-chloride. The sulphate of copper and alum (ter-sulphate of alumina and potash), with the sulphate of iron, when heated, evolve sulphuric acid, which, decomposing the saltpetre, liberates nitric acid. The muriate of ammonia is decomposed at the same time, sulphate of ammonia being formed, and muriatic acid set free. The muriatic and nitric acids meeting in vapour, form water and evolve *chlorine.* The vapours of calomel simultaneously rising and meeting the chlorine are converted into the bi-chloride of mercury, the preparation described.

The close resemblance of this ancient method to that practised in Holland at this day is very remarkable. Indeed, were it an object to devise a process for the cheap manufacture of corrosive sublimate from bazar materials and bazar vessels, the most accomplished chemist could make but little improvement in the sagacious though empiric formula of the Tamuls.

These precepts could only have resulted from the closest combination of observation of chemical phenomena, and of the medicinal effects of the remedies prepared. With precisely similar habits, and with all the aid of modern science, the descendants of these extraordinary men may be reasonably expected to contribute much to the progress of chemical and pharmaceutical knowledge.

SECTION XXIV.

SILVER AND ITS COMPOUNDS.

Silver (روپا *rúpá*) is often found in the pure state, but is usually obtained in combination with sulphur, lead, antimony, copper, and other metals. It is reduced from its ores by different processes, two of which demand especial notice.

When associated with lead, the ore is exposed to heat in a furnace fully open to the air. The lead is oxidized, fuses, and is drawn off in that state, while a mass of solid silver remains. The silver is again fused on a dish made of wood or bone ashes: any adhering lead being oxidized unites with the alkali of the ashes, and pure silver remains.

In Saxony and in South America the native silver and its sulphuret are roasted with salt in a reverberatory furnace. A chloride of silver is thus produced. This is mixed with mercury, water, and iron, and the mixture set in rapid motion in vessels moved by machinery. Chloride of iron is formed, and the silver and mercury combined constitute an amalgam, which, when heated in close vessels, yields the mercury, while the silver remains.

To obtain perfectly pure silver for chemical purposes, a solution of the nitrate of silver is to be precipitated by salt. Chloride of silver is thrown down, and must be washed and dried. Two parts of carbonate of potash are next fused in a black lead crucible, and the chloride of silver thrown in by degrees. Carbonic acid is expelled, chloride of potassium formed, and metallic silver subsides.

But few details are required relative to the physical properties of silver. Its density is 10.51. It does not rust on exposure to the air, but, when melted in open vessels, it absorbs several times its volume of oxygen, which it gives off again on cooling. If the silver contains the least trace of copper, this oxidation does not occur.

Hot sulphuric acid oxidizes silver, and forms a salt with the oxide. Nitric acid dissolves it rapidly at all temperatures, producing a salt subsequently described. The equivalent number of this metal has been determined by Dr. Turner's recent researches to be 108°, 3, oxygen scale, 1351.6.

The *Oxide of Silver* is obtained from the nitrate by adding baryta. It is brown, insoluble in water, and reduced to the metallic state at a red heat. This oxide is soluble in ammonia, and with the acids forms neutral salts, which possess the property of yielding the metal in a *tree*-like precipitate, when several other metals are introduced into their solutions. Thus, 20 grains of nitrate of silver dissolved in one ounce of water, and mixed with metallic mercury, soon deposit the silver in a very beautiful vegetation. When the oxide of silver is dried and steeped in strong ammonia for some hours, a black powder is left, which explodes violently when heated or smartly struck, metallic silver being left, and nitrogen and water evolved.

The *Chloride of Silver*, (chlorine 1 eq. silver 1 eq.) is formed by adding muriatic acid, or its salts, to a solution of nitrate of silver. A dense white chloride of silver is precipitated, the hydrogen of the muriatic acid, and oxygen of the oxide of silver forming water, while the chlorine and the metal combine. This chloride is insoluble in water or nitric acid, but is dissolved freely by ammonia. When exposed to the sun's rays it is rapidly blackened, some oxide of silver being formed, and muriatic acid set free.

The chloride of silver fuses at 500°, and concretes in a transparent mass called "horn-silver," a substance sometimes found in silver mines. When the fused chloride is heated with potash, or exposed to a current of hydrogen gas, the chlorine is separated and metallic silver obtained.

The *Sulphuret of Silver* is made by passing a current of sulphuretted hydrogen gas through a solution of nitrate of silver. It is black, soft, and malleable, and in the native state constitutes the *silver glance* of mineralogists.

SALTS OF SILVER.

These are recognized easily by the properties of the precipitate they afford with solutions of common salt, and with sulphuretted hydrogen.

The *Nitrate of Silver* or "lunar caustic" is made by dissolving pure silver in dilute nitric acid. On evaporation transparent tabular crystals are formed, which are readily fused in a porcelain vessel. When cast in moulds of copper or iron, the well-known "caustic" of surgeons is obtained. The fused nitrate of silver is white, opaque, and crystalline, soluble in its own weight of cold, and half its weight of hot water. It is frequently contaminated with copper. It gives a black stain to animal matters, but though it blackens solutions of organic matter when exposed to the light, pure nitrate of silver dissolved in distilled water is not altered in colour.

Nitrate of silver, when long taken internally, frequently changes the colour of the skin to an indelible livid black hue. Several methods of removing this discoloration have been proposed, and all have proved alike ineffectual.

The nitrate of silver in solution is kept in all laboratories as a test for chlorine and its soluble compounds. *Marking ink* is made of a solution of this salt with a little gum water. The fabric to be marked is previously moistened in a solution of carbonate of soda.

Sulphate of Silver, a very useful article in the laboratory, is made by mixing saturated solutions of sulphate of soda and nitrate of silver. The sulphate of silver is precipitated. It is soluble in a large quantity of water.

The fulminating *Cyanate of Silver* is made by dissolving 100 grains of silver in an ounce and a half of strong nitric acid. The solution when cold is to be added in small quantities to two ounces of alcohol, which is to be quickly heated until white fumes appear. A white compound soon forms, in dense flakes. This must be washed on a filter and allowed to dry spontaneously. In this state it detonates by heat, percussion, or friction.

SECTION XXV.

GOLD AND ITS COMPOUNDS.

Gold (*Soná* سونا) occurs either pure or combined with other metals, from all of which, except silver, it is refined by the amalgamation process described in the last section. On heating the amalgam to redness, the mercury is expelled, and treating the residue with nitro-hydro-chloric acid, chloride of silver is precipitated, and chloride of gold remains in solution. But the best method is by fusing the impure gold with three-fourths of its weight of silver. The mass is then treated with sulphuric or nitric acid, which dissolves the silver and gold.

Gold is distinguished by its yellow colour, its peculiar malleability and ductility, and its great density (19.3). It does not combine with oxygen by exposure to the air even when heated to redness. It is not oxidized or dissolved by any of the acids, but chlorine, or a mixture of the nitric and muriatic acids dissolve it freely. The equivalent of gold is 199.2.

The *Protoxide of Gold* is green, the *Binoxide* purple. The *peroxide* is the compound, the properties of which are best known. Dr. Wagner prepares it by dissolving one part of gold in nitro-muriatic acid, evaporating to dryness, re-dissolving in 12 parts of water. To the solution, one part of carbonate of potash is added, and the mixture is heated to 170°. Carbonic acid gradually escapes, and a brownish red peroxide of gold subsides.

This peroxide unites with alkalies forming salts called *aurates*. With ammonia it forms a violently explosive mixture.

The *Chlorides of Gold* are three. The *ter-chloride*, made by dissolving gold in a mixture of one part of nitric and two muriatic acid, is obtained on evaporation in ruby red crystals, soluble in alcohol and ether, and deliquescent in the open air. At a red heat all the chlorine is expelled. On the addition of a solution of proto-sulphate of iron, metallic gold is deposited, and chloride of iron remains in solution. A similar effect is produced by several metals and by charcoal.

From a solution of this chloride ammonia throws down a precipitate which, when left to dry on a filter at ordinary temperatures, detonates powerfully when heated or rubbed.

When proto-chloride of tin is added to a dilute solution of gold in water, a purple precipitate, called the "powder of Cassius," is thrown down. The same substance may be prepared by fusing together 150 parts of silver, 20 of gold and 35.1 of tin. By acting on the alloy with nitric acid the silver is dissolved, and a purple residue is left. This powder when fused with glassy compounds or enamels, gives them a rich pink colour. It is soluble in ammonia, and its precise chemical nature is still uncertain.

SECTION XXVI.

PLATINUM AND ITS COMPOUNDS.

Platinum for many reasons deserves much attention.

The ore of this costly, but equally useful metal was long thrown aside as valueless in the South American mines, where it was first noticed. At length its extraordinary weight attracted attention, and through the researches of Scheffer and Wood, the existence of the metal was fully ascertained.

The chief sources of the platinum now found in commerce occur in Peru, Brazil, and other parts of South America. In the Uralian mountains, it has been found in large quantities in combination with gold. Very recently too, specimens of platinum ore have been found in Ava, and subjected to analysis by Mr. Prinsep, who detected in them, besides platinum, the metals called osmium, iridium, and palladium, described in another section.

Platinum is greyish-white, highly tenacious, ductile, and malleable. Its specific gravity ranges from 19.50 to 21.5. It is infusible in the most powerful blast furnaces, but melts before the oxy-hydrogen blow-pipe, emitting intense light, and producing showers of brilliant sparks. It is not oxidized by being heated in air or oxygen gas. It does not decompose water, is unaffected by pure acids, its best solvent being the nitro-muriatic acid. It is corroded by alkalies, especially by lithine, and by a mixture of alkalies and nitre. The alkaline sulphurets also corrode it, but sulphur does not unite with it, except when the metal is very minutely divided.

Three varieties of platinum may be distinguished,—the massive, spongy, and precipitated.

The *massive* presents the characters above described. When beaten into thin leaves, and their surfaces perfectly clean, it possesses the remarkable property of becoming red hot in, and exploding a mixture of, oxygen and hydrogen gases.

The *spongy platinum* is prepared by dissolving 120 parts of platinum in nitro-muriatic acid, and adding a solution of 41 parts of muriate of ammonia, and 205 parts of water. A yellow precipitate is thrown down, which must be well washed and pressed. On heating this in a small covered crucible to low redness, the metal is obtained in the state of a spongy mass, which is characterized by its becoming red hot when exposed to a stream of hydrogen gas. It also causes the combination of several gases with each other, of which carbonic oxide and oxygen afford an example.

By steeping filtering paper in a solution of platinum in nitro-muriatic acid, drying the paper, and repeating this three times, the ashes of the paper when burned contain very finely divided platinum, which acts on gaseous mixtures still more powerfully than the sponge. By precipitating a very acid solution of platinum by zinc, a similar powder is obtained, the minutest particle of which causes instantaneous explosion of several gases.

By making a spiral coil of about ten turns of platinum wire, and placing it round the wick of a spirit lamp, on lighting the lamp the wire becomes red hot. If the lamp be now blown out, the wire still continues ignited, and remains so until all the spirit is consumed. A similar coil heated far below redness, if introduced into a mixture of coal gas and atmospheric air, immediately becomes red hot, and explodes the mixture.

But of all the varieties of platinum, the platinum black, described by Liebig, is the most curious. Pure chloride of platinum is mixed with a concentrated solution of potash. The chloride is dissolved on heating the solution. Alcohol is very gradually added, brisk effervescence occurs, and a velvet black powder is thrown down, which must be successively washed with dilute muriatic acid, potash, and water. These washings must be separated five or six times, and the powder then dried on a porcelain capsule. In this state it is granulated and hard, is not affected by heat, by air, by oxygen or hydrogen gas. But when moistened with a little alcohol in contact with air or oxygen, it becomes instantaneously ignited, and continues so as long as alcohol is supplied. The alcohol is converted into acetic acid. A particle of this "platinum black," so small as scarcely to be perceptible, occasions an instant explosion of a mixture of oxygen and hydrogen gas.

The combining number of platinum is shewn by Berzelius to be 98.8, or 1233.5 on the oxygen scale.

Three oxides of platinum have been described. They are all prepared with difficulty, and exhibit no interesting properties. There are two chlorides, of which the bi-chloride is the most remarkable. Its mode of preparation I have already described. This chloride possesses in many respects the properties of an acid, and forms compounds termed "double chlorides" with the chlorides of the alkali and earthy bases. A solution of the chloride of platinum gives a pale yellow precipitate with saturated solutions of the salts of potash. This precipitate is insoluble in alcohol, and very sparingly dissolved by water. With a solution of muriate of ammonia the chloride of platinum gives the yellow precipitate already described, from which the spongy platinum is obtained. When this compound is digested in nitro-muriatic acid, the chloride of nitrogen, the most dangerous of all explosive substances is formed.

Platinum vessels are of the utmost use in the laboratory, they are so little affected by acids or by heat. The scarcity of the ore and the difficulty of the manufacture, unfortunately, render their price beyond the means of most students in this country. A slip of platinum foil, however, costs very little, and will be found of great utility in a multitude of experiments.

For the details of the working of platinum, I must refer to Dr. Wollaston's paper in the Philosophical Transactions for 1829.

SECTION XXVII.

PALLADIUM, RHODIUM, OSMIUM, AND IRIDIUM.

These metals are all contained in the ore of platinum, and have been found in very small quantities. When the ore is heated with nitro-muriatic acid, the platinum, palladium, and rhodium are dissolved, while the osmium and iridium remain as a black powder.

Palladium is prepared by adding a solution of bicyanuret of mercury to a solution of platinum *ore* in nitro-muriatic acid; cyanuret of palladium is thrown down, which, when heated to redness, evolves cyanogen, and the metal is left. It is white, ductile, and malleable, sp. gr. 11.5. more fusible than platinum, less so than gold. When heated in oxygen gas its surface acquires a fine blue colour, owing to superficial oxidation. It is soluble in the nitric, sulphuric, and muriatic acids, and its oxide forms with the acids salts of a fine red colour.

The equivalent number of palladium is 53.3. It unites with oxygen and chlorine in two proportions. Its sulphuret is grey, while that of platinum is black.

Rhodium remains in the solution from which the palladium has been precipitated. On introducing a slip of clean iron, the rhodium is thrown down along with the platinum, copper, and lead. The two last metals are removed by nitric acid, and the rhodium and platinum are then dissolved by nitro-muriatic acid. Sea-salt is added, and the solution evaporated to dryness. Double chlorides of rhodium and platinum are thus formed, the former of which is soluble, the latter insoluble in alcohol. The alcoholic solution is evaporated to dryness, dissolved in water, and on introducing a rod of zinc the chloride of zinc is formed, and rhodium precipitated as a black powder. This is fused by the strong heat of a wind furnace, and after being melted is of a white colour. It is hard, and brittle; its sp. gr. 11°. When pure it is insoluble in acids, but if alloyed with copper or lead it is dissolved by the nitro-muriatic acid. When heated with bi-sulphate of potash, sulphurous acid gas is evolved, and a soluble double sulphate of oxide of rhodium and potash is generated. The combining number of rhodium is 52.2. There are two oxides, the protoxide black, the peroxide yellow. The chloride in solution is of a fine rose-red colour. The sulphuret is bluish grey with metallic lustre.

OSMIUM AND IRIDIUM.

The black powder remaining after the action of nitro-muriatic acid on platinum ore, is a mixture of these metals, resulting from a natural alloy, which may be found in white flat grains in the ore itself.

This alloy is heated to redness with nitre in a silver crucible. When an odour resembling chlorine is perceived, the process is stopped, and the soluble parts which contain oxide of osmium removed by a small quantity of water. Acidulate the solution with sulphuric acid, and distil from a retort. The oxide of osmium is volatilized, and collects as a white crust on the sides of the receiver. The oxide melts when the receiver becomes warm, and as it cools concretes in a white crystalline mass.

This oxide is insoluble in acids, but unites with alkalies, forming compounds sometimes called *osmates*. Its vapour is very acrid. It stains the skin. With infusions of gallnuts it gives a purple solution. By sulphurous acid it is deoxidized, and the colour of the solution passes through various shades of yellow, orange, brown, green, and blue.

The oxide of osmium in solution is reduced to the metallic state by iron, zinc, copper, and many other metals. When thus precipitated it is left as a black porous powder, of metallic lustre; sp. gr. 10; combining equivalent 99.7, soluble in nitric acid, and oxidized by being heated to redness in the open air.

A minute description of the oxides and chloride of osmium would be altogether superfluous in an elementary treatise.

IRIDIUM remains in the insoluble portions of the mass from which *osmium* was removed. By acting on this with muriatic acid a blue solution is obtained, which afterwards becomes green, and finally red. The red solution is bleached by the alkalies, and decomposed by all metals, except gold and platinum—iridium being thrown down in the metallic state. It is brilliant, white, and brittle, the most infusible of all known metals. Specific gravity 15.86. It is insoluble in all acids but the nitro-muriatic. Its equivalent number is estimated at 78.8. There are four oxides, and four chlorides, of distinct but unimportant properties.

ECTION XXVIII.

THE LAWS OF COMBINATION.

Having now completed our examination of the elementary bodies, and their most remarkable inorganic compounds, we are prepared to review, briefly, the mode in which these elements are associated, and the laws by which their combinations are regulated. I have already alluded to this subject in the first section of this Manual, and I now return to it, with a view to impress its important details on the memory of the student. The knowledge of these admirable laws is the greatest triumph which chemistry has yet achieved, and constitutes one of the most admirable of the links which science has established in the connexion between the philosophy of induction and experiment.

Of the compounds we have examined, some unite in all proportions, such as alcohol and water, water and the acids, and numerous salts, &c.;—others, and the most remarkable bodies unite in fixed and few proportions with each other, and after their union lose many of the properties by which they were distinguished. Thus sulphur is a yellow solid, oxygen is a colourless gas; united in the proportion of one to three, they form a dense liquid,—the corrosive sulphuric acid. With these again the alkali potash constitutes a salt, in which neither acid nor alkaline qualities are apparent.

Now all these substances which unite in fixed proportions, are found to observe the three subsequent laws of combination.

First. The composition of these bodies is invariable; thus 8 parts of oxygen and 1 of hydrogen form water; but were 12 or 16 of oxygen to combine with 1 of hydrogen, another compound would result. Sea-salt contains 35.42 parts of chlorine and 23.3 of sodium—no other chloride of sodium exists naturally. The salt which has accumulated in mines, the æra of the formation of which we can scarcely speculate on, is the same in its composition, identical in its properties with that which we procure by the artificial admixture of its elements in the due proportion. And if we change the quantities, and add more chlorine or more sodium, still we cannot change the operation of the power which arranges the uniting elements, and measures these in due quantity to each other. Whatever we add in excess remains unapplied in the mixture.

The second law is, that the relative quantities on which bodies unite may be expressed in proportional numbers. Thus, 1 part of hydrogen unites with 8 of oxygen or 16 of sulphur, and 35.42 of chlorine and 126 of iodine.

The word "equivalent" is usually employed to designate these numerical relations. They hold good, too, with compounds composed of several elements. Thus, nitric acid is composed of nitrogen 14.15, oxygen 40=54.15. Potash contains potassium 39.15, oxygen 8=47.15. The equivalent of the nitrate of the potash is hence 101.15. Again, 18 of lithine, 20.7 of magnesia, 28.5 of lime, 31.3 of soda, 47 of potassa, 51.8 of strontia, and 76.7 of baryta, all are equivalent to, or neutralize exactly the same quantity of any given acid, such as 54.15 of nitric, or 40 of sulphuric acid.

The necessary and important result of this law is, that when two neutral salts of different composition decompose each other, the resulting bodies are neutral also. Thus 130.7 parts of nitrate of baryta, decompose 71.3 parts of sulphate of soda, and neutral sulphate of baryta and nitrate of soda result.

The third law of combination is, that when bodies unite in several proportions, these bear a simple ratio to each other. In one series it unites with 1, 2, 3, or 4 of B.: in a second it unites with 1, 1½, 2, 2½ of B. Thus water contains 1 eq. of oxygen 8, and 1 eq. of hydrogen 1.9. The peroxide of hydrogen contains 2 eq. of oxygen 16. Carbonic oxide is composed of carbon 6, 1 eq., oxygen 8, 1 eq. Carbonic acid contains exactly double that quantity of oxygen.

Nitrogen and oxygen form 5 definite compounds bearing the simple ratio of 1, 2, 3, 4, 5 of oxygen to 1 of nitrogen. Oxalic acid and potash again form three salts, having the separate and simple proportions of 1, 2, 3 of acid to 1 eq. of the base. The second series is exemplified well by manganese, the protoxide containing the full equivalents, (manganese 27.7, oxygen 8,) the sesquioxide composed of manganese 27.7, oxygen 12, or in the proportion of 1 and 1 ½ to 1.

The mode in which the equivalent numbers are expressed varies in different countries. Thus some chemists while they fully admit the preceding facts, still call oxygen unity, and make hydrogen and all other bodies bear the *same proportion* to this unit that they do in the present scale. The inconvenience of this method is obvious. It introduces a multitude of fractions into a calculation which should be pre-eminently simple. For although Prout was in error, when he stated that the use of hydrogen as the unit would permit us to express all the other elements in whole numbers, still the nearest approximation to this is to be obtained from the unit he proposed, and which is now almost universally adopted by British chemists.*

The equivalent numbers are ascertained by analytic and synthetic processes. Thus analysis shews that nine grains of water, when decomposed by a galvanic current, generate 21.75 cubic inches of mixed oxygen and hydrogen gases. Again, by burning 21.75 cubic inches of hydrogen and oxygen in the proportion of 2 measures hydrogen to one oxygen, 9 grains of water are procured. These results are checked by varying the process in another manner. A known weight of hydrogen is passed over a certain quantity of peroxide of copper, heated to low redness in a glass tube. Water is formed, and absorbed by chloride of calcium placed in another tube. The consumption of hydrogen, the loss of weight of oxide of copper, and the increase in that of the chloride of calcium, give certain

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* In this edition I have inserted the equivalents on both scales.

data by which the equivalents of oxygen and hydrogen can be synthetically determined.

The most conclusive evidence hitherto obtained of the truth of the laws I have enumerated, is that recently published in Dr. Faraday's unrivalled researches in galvanism. If by any suitable apparatus a powerful current of galvanic electricity is set in motion, and applied as a decomposing agent, the results are in the precise ratio of the chemical equivalents of the decomposed bodies. Thus, if a galvanic battery, composed of zinc and copper, analyse successively common water, chloride of lead and chloride of silver, 9 grains of water are decomposed, 103.6 grains of lead, and 108 grains of silver obtained, and 32.3 grains of zinc dissolved from each plate of the galvanic circle.

I have already given a table of the exact chemical equivalents ascertained by Berzelius, Turner, and other authorities. In many instances in the preceding pages I have omitted the fractions, with a view to simplify calculation, especially in treating of manufacturing processes.

To all persons engaged in chemical pursuits, the knowledge of equivalent numbers is of the utmost advantage. It directs the proportions in which ingredients are to be mixed to obtain a particular result, and it corrects in many the errors of our manipulation. It enables us to infer the composition of one substance from our knowledge of the composition of another; and it serves us as an artificial memory for the recollection of numerical data, otherwise of the utmost complexity.

The facts above described, constitute the foundation for Dalton's celebrated Theory of Atoms. He supposes that all the elementary varieties of matter are made up of indivisible particles of a spherical shape; that these particles differ in weight; that they combine in definite proportions; and that where two elements give rise to several compounds, these bear a simple multiple proportion to each other. It is needless to dwell on the remarkable accordance of this theory with the facts experimentally established. The weakest point is that which relates to the sphericity of the ultimate particle, although the study of the mathematical formation of crystallized bodies strengthens even this recondite speculation.

Besides the laws by which the combining proportions of the weights of compounds are regulated, the gases are found to combine in definite proportions of bulk or measure.

Thus, when we decompose water by galvanism, the hydrogen evolved bears the exact proportion of two measures to one of oxygen. Ammonia when passed through a red-hot porcelain tube gives three measures of hydrogen and one of nitrogen. Nitrogen again with 1, 2, 3, 4, and 5 measures of oxygen successively forms nitrous oxide, nitric oxide, the hypo-nitrous, nitrous, and nitric acids. Here then the ratio of the combination of the simple gases by volume is in exact simple multiple proportion.

The union of compound gases is also obedient to the same law. Thus equal measures (say 100) of muriatic acid gas and ammoniacal gas, constitute the salt called muriate of ammonia, and these gases will not unite in any other proportion. The same facts are observed in the compounds of ammonia with the carbonic and fluo-boric acids. The law holds good, too, with the compounds of vapours and gases, such as hydriodic acid and sulphuretted hydrogen; the volume of the vapour bears a simple ratio to the volume of the gas.

The compounds produced may differ in volume from the joint volumes of their component gases, but still the volume of the new compound bears a simple ratio to that of the original gases.

Thus 300 measures of hydrogen and 100 of nitrogen produce 200 of ammonia; 50 of oxygen, and 100 of hydrogen generate 100 of the vapour of water; 100 nitrogen and 50 oxygen form 100 of nitrous oxide.

These facts supply a ready mode of calculating the specific quantities of compound gases, from the known specific gravity of one or more of their constituents, the volume in which the gases combine, and the resulting volume they produce.

Thus protoxide of nitrogen contains 100 volumes of nitrogen and 50 of oxygen, condensed into 100. Hence its specific gravity should be 0.9727 (the sp. gr. of nitrogen) and 0.5512 (half the sp. gr. of oxygen)=1,5239. Reference to the sections on the gases will supply the student with many additional illustrations of this law.

CLASSIFICATION OF SALTS.

All saline compounds which have a certain similarity of composition, may be grouped together into one great class of *salts*, which is divided into the four following orders :—

Order I. The oxy-salts. This order includes no salt the acid or base of which is not an oxidized body.

Examples: sulphates, nitrates, carbonates, cyanates, &c.

Order II. The hydro-salts. This order includes no salt the acid or base of which does not contain hydrogen.

Examples: hydro-sulphurets, (SH.) hydro-cyanates (Cy. H.) If the acids are united with oxides, on being dried an equivalent of water is usually formed, and a dry sulphuret remains.

Order III. The sulphur-salts. This order includes no salt the electro-positive or negative ingredient of which is not a sulphuret.

Order IV. The haloid-salts. This order includes no salt one ingredient of which is not haloidal, or resembling sea-salt.

The two last classes require some explanatory remarks.

The notion of a salt has of late been much extended. Chemists have long known that metallic sulphurets occasionally combine together, and constitute what is called a *double sulphuret*. In these compounds Berzelius, whose labours have greatly added to their number, has traced an exact analogy with the salts, and applied to them the name of *sulphur-salts*.

The simple sulphurets, by the union of which a sulphur-salt is formed, are bi-elementary compounds, strictly analogous in their constitution to acids and alkaline bases, and which, like them, are capable of assuming opposite electric energies in relation to each other.

The compounds which Berzelius has enumerated as sulphur-acids, are the sulphurets of arsenic, antimony, tungsten, molybdenum, tellurium, tin, and gold. To these he has added the sulphurets of several other substances not metallic, such as sulphuret of selenium, bi-sulphuret of carbon, and the hydro-sulphuric and hydro-sulphocyanic acids.

The fourth order of salts has been formed by Berzelius, comprising for the most part bi-elementary compounds, which consist of a metal on the one hand, and of chlorine, iodine, bromine, fluorine, and the radicals of the hydracids on the other. He has applied to them the name of *haloid-salts* (from ἅλς sea-salt, and ειδος form), because in constitution they are analogous to sea-salt. The whole series of the metallic chlorides, iodides, bromides, and fluorides, such as chloride of sodium, iodide of potassium, and fluor-spar, as well as the cyanurets, sulpho-cyanurets, and ferro-cyanurets, are included in his list of haloid-salts.—(*See Turner's Chemistry,—last Edition.*)

SUBSTITUTIONS AND ISOMORPHISM.

Several very remarkable instances have been accumulated of late years in which in various compound bodies one or more of the constituents may be removed and replaced by another, without the secondary properties of the resulting body being materially altered.

Thus the oxide of sodium, iron, chrome or manganese may replace that of potassium in alum, without the crystalline form, colour, taste, or solubility of the new compound differing from the first.

Where the form remains the same, the composition being altered, this is called *isomorphism*, and such compounds are termed *isomorphous*. This may occur however without any analogy existing in the composition of the similar substances.

The term *isomerism* (equal proportions) is applied to bodies which having the same composition, as far as the number and proportion of their elements, still differ in secondary properties. Thus the series of carburets of hydrogen

$$C_2.\ H_2.$$
$$C_4.\ H_4.$$
$$C_8.\ H_8.$$

have the same elements in the same proportions, but the resulting compounds differ totally from each other in their secondary properties.

It frequently happens that one element may be *substituted* for another in a compound body, and that great analogy will exist in the chemical habits of the bodies formed. Sulphur, chlorine, and iodine, are thus frequently substituted for oxygen; hydrogen for an equivalent of a metal. Water in corresponding proportion often substitutes an equivalent of a metallic oxide, as is remarkably shewn in the composition of the phosphates of soda.

Graham has recently attempted to shew that the common views regarding the composition of several highly important salts may be more simply represented by grouping their constituents in a manner different to that now adopted.

He thus supposes that when sulphuric acid (S_1, O_3.) unites with an oxide of a metal (M. O. $_1$.) a compound $S_1.O_4$. which he calls sulphat-oxygen is formed, which unites directly with the metal, forming S. O_4. M. instead of S. O_3. M. O. Nitric acid will thus give nitrat-oxygen N1. Ox. 6.

—the law of combination being the same as that affecting the compounds of cyanogen and other compound radicals.

Facts are still wanting to support this theory, which nevertheless is still daily gaining new and distinguished adherents. The medical student must however be taught to regard such novelties with caution, as the result of their adoption must be another revolution in the nomenclature of chemical remedies, an evil of serious magnitude, and certain to occasion dangerous mistakes in the most practical department of the medical art.

PART THE THIRD.

ORGANIC CHEMISTRY.

PRELIMINARY REMARKS.

ORGANIC chemistry comprehends all substances of animal or vegetable origin. These generally consist of oxygen, hydrogen, and carbon: many contain nitrogen; and in most, minute portions of iron, phosphorus, lime, silicium, and other substances may be detected in various states of combination.

When organic matters are heated to redness with potash or soda, they yield pure carbonates. Between 400° and 500° many are decomposed, and form oxalic acid.

Most organic compounds are liable to decay from the operation of various causes, to be described in the section on fermentation. But few can be artificially generated according to the present state of chemical knowledge; but discoveries are constantly making, which promise to give the chemist extended powers of combination more than it was ever supposed he could possess.

All organic substances are decomposed by a red heat, and many by a temperature far lower. Heated in the open air, their combustion generates water and carbonic acid; but in close vessels carbonic oxide and carburetted hydrogen are also evolved. Acetic acid and a volatile empyreumatic oil are also often produced in this way.

The *ultimate* analysis of organic principles is a very difficult operation, though founded on the simplest theory. The substance for examination is first perfectly dried by confining it, while heated to 212°, under the exhausted chamber of an air-pump along with sulphuric acid, or by placing it in a glass tube heated by immersion in a bath of muriate of lime, and exposed to a current of air led through the tube. The next step of the process is to convert the carbon of the subject under analysis into carbonic acid, and its hydrogen into water by means of oxygen. Oxide of copper is used for this purpose, as it may be heated to whiteness without evolving oxygen, unless some combustible substance be mixed with it to which it readily supplies all the oxygen required for its perfect combustion.

Three or four grains of the organic matter are mixed with 200 grains of the oxide of copper in a glass tube, and heated to redness. The gaseous products are led through a little bulb containing dry chloride of calcium. The increase of weight of the chloride of calcium indicates eight grains of oxygen and one grain of hydrogen for every nine grains of water absorbed. From this bulb the gases pass through a series of similar bulbs filled with a solution of caustic potash. The increase of weight after the experiment shews the amount of carbonic acid formed from which the carbon may be calculated. When nitrogen exists in the substance analysed, it passes over in the gaseous state, and is collected and measured in a graduated jar.

Some finely divided metallic copper is usually mixed with the peroxide to prevent the formation of nitric oxide, which otherwise is apt to occur.

The weight of the different products should of course be equal to that of the substance examined.

When fluids are analysed these are either made into a paste with the oxide of copper, or their vapours are conducted over the oxide heated to redness.*

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* For exact details, consult Dr. W. Gregory's translation of *Liebig's Organic Analysis*, in Griffin's Scientific Miscellany.

SECTION I.

VEGETABLE PRODUCTS.

Vegetable products consist essentially of oxygen, hydrogen, and carbon; and occasionally contain nitrogen, sulphur, and other substances in minute proportions. A plant, or fruit, or any of their products, such as opium or the extracts of vegetables, consists of several *proximate* or *immediate* principles, such as sugar, gum, starch, fibre, &c.

The separation of these proximate principles constitutes the most important object of vegetable chemistry. I shall follow Dr. Turner in his original arrangement of the subject, which he divides into seven sections. The first treats of the vegetable acids; the second of the vegetable alkalies; the third of neutral substances, the oxygen and hydrogen of which are in the ratio to form water; the fourth contains oil, resins, and bituminous substances; the fifth, spirituous and etherial principles; the sixth, colouring matters; and the seventh, miscellaneous substances not referable to the other divisions.

In the last edition of the work just quoted (and published since Dr. Turner's death), a totally different arrangement is given, which it would be premature to adopt in an elementary class book.

VEGETABLE ACIDS.

OXALIC ACID.

Oxalic acid exists in several plants, especially in those of the sorrel family (چوکه *chuka.*) It is associated with potash, and sometimes with lime, as in the rhubarb and various lichens. It can be prepared artificially by heating sugar with five times its weight of nitric acid. Effervescence ensues, owing to the escape of nitric oxide, and on cooling, long prismatic crystals of oxalic acid are deposited. Starch, gum, several vegetable acids, hair and silk, yield this acid when similarly treated. It is also formed, as already stated, by heating potash or soda with organic matters to the temperature of 450°.

The crystals of oxalic acid are long, slender, four-sided prisms, with summits having two sides. It is very sour, and possesses all the characteristic properties of a strong acid. The crystals contain 3 equivalents of water, in which they fuse when heated to 209°. Water at 60° dissolves nine times its weight of this acid, and it is also soluble in alcohol.

The oxalic acid is composed solely of carbon 2 eq. and oxygen 3 eq.: or, in other words, of 1 eq. of carbonic acid and 1 eq. of carbonic oxide, combined with 3 eq. of water. Accordingly on heating the crystals with strong sulphuric acid, the water is withdrawn, and equal measures of carbonic acid and carbonic oxide are obtained. I have lately found, too, that fused oxalic acid, when decomposed by the galvanic battery, yields precisely the same products.

When oxalic acid is heated suddenly to 300° it yields formic acid, a compound of 2 eq. carbonic oxide and 1 eq. of water, together with carbonic oxide and acid.

Oxalic acid is distinguished from other acid bodies by its form, by its producing a white precipitate with lime, the oxides of lead and of silver, and by the oxalate of silver when heated exploding faintly, owing to the sudden production of carbonic oxide and acid gases. The oxalates of lime and lead, when heated to low redness, become carbonates of the oxide of these metals.

SALTS OF OXALIC ACID.

The *Oxalates of Potash* are three, the protoxalate, binoxalate and quadroxalate. The second of these is often sold under the absurd name of " essential salt of lemons," and is used for removing iron moulds from clothes, which it effects by its excess of acid dissolving the peroxide of iron, with which it forms a very soluble compound.

The *Oxalate of Ammonia* is prepared by neutralizing ammonia with oxalic acid. It is much used as a test for lime. When heated in a retort it is decomposed, and a white substance, called *oxamide*, is formed. This is insoluble in cold, soluble in boiling water, and yields cyanogen gas when suddenly heated. On ultimate analysis it is found to contain 2 eq. of carbon, 1 eq. nitrogen, 2 hydrogen, and 1 oxygen; or, in other words, 1 eq. of cyanogen and 1 eq. of water.

The *Oxalate of Lime* is formed by adding a solution of any oxalate to a solution of lime. The precipitate contains 36.14 parts of acid, and 28.5 of lime. This compound frequently occurs as a urinary deposit, and often forms in the bladder large concretions termed the *mulberry calculus,* from their peculiar reddish and berry-like aspect.

The *Oxalate of Magnesia* is made by adding a solution of oxalate of ammonia to a hot saturated solution of sulphate of magnesia. It is a white powder, much more soluble than the oxalate of lime. Hence, on treating a dilute solution of the mixed sulphates of lime and magnesia with oxalate of ammonia, oxalate of lime subsides, and oxalate of magnesia remains in solution. This fact is applied advantageously in analysis in the separation of these earths from each other.

Oxalic acid, owing to its composition, is readily converted into carbonic acid. Thus, when mixed with peroxide of manganese and sulphuric acid, the oxygen liberated forms carbonic acid, with the oxalic acid. In the assay of manganese ores, by means of oxalic acid, previously described as the ore itself often contains carbonates of lime, it is necessary, in order to remove the carbonate of lime, to wash the powder well with very dilute muriatic acid, and then to dry it before proceeding with Dr. Thomson's process; otherwise it is obvious that a deceptive result might be obtained, owing to the decomposition of the carbonate of lime by the sulphuric and oxalic acids.

Oxalic acid and its soluble salts are violent acrid poisons.

ACETIC ACID.

Acetic acid is the basis of vinegar. United with lime or potash, it exists in many plants. It is generated during the fermentation of wine and malt liquors, and by distilling wood in iron retorts. It is formed also during the slow combustion of alcohol in contact with platinum black, or ignited spirals of platinum wire.

Common vinegar is the result of the fermentation of wine, or sugar; distilled vinegar is obtained from the common kind, and by the distillation is freed from sugar, mucilage, and other impurities.

What is called *pyro-ligneous* acid, is acetic acid prepared by the destructive distillation of wood. The impure acid thus obtained is combined with lime or soda, and the resulting acetate of lime decomposed by sulphuric acid.

Strong acetic acid is colourless, volatile, inflammable, of pungent odour, and sharp sour taste. It is composed of 4 eq. carbon, 3 eq. hydrogen, and 3 eq. oxygen. In its most concentrated state it contains 1 eq. of water. When of this strength it crystallizes at 50° Fahrenheit.

The strength of distilled vinegar cannot be estimated by its specific gravity, as an acid containing 4 parts of water is denser than an acid containing but 10. The specific gravity of the former is 1.074; of the latter, 1.054. The best criterion is the quantity of pure carbonate of lime it will decompose and dissolve.

The acetates of potash, ammonia, baryta, alumina, zinc, copper, lead, and mercury have been described in treating of their respective bases.

Acetone, or the *Pyro-acetic Spirit*, is obtained by distilling the salts of acetic acid. When dry acetate of baryta is distilled in close vessels, the acetic acid (carbon 4, oxygen 3, hydrogen 3) is resolved into carbonic acid (carbon 1, oxygen 2), and this pyro-acetic spirit, which is a compound of 3 eq. carbon, 1 oxygen, and 3 hydrogen. It is a colourless liquid, spec. gr.

0.792; boils at 132°; its vapour burns with a brilliant white flame, and deposits no soot.

Another liquid called *Pyroxylic Spirit* has also been examined. It is obtained during the preparation of wood vinegar, and resembles alcohol in many of its properties.

Pyroxylic spirit has recently been described as the hydrated oxide of a compound organic radical, composed of carbon 2 eq: hydrogen 3 eq: and termed *Methule* (C_3. H_2.) This radical is merely hypothetical; but the series of compounds derived from the re-action of pyroxylic spirit with other substances lend strong probability to the opinion of its existence.

It is supposed to resemble Ethule in its chemical relations. The anhydrous oxide of *methule* is a gas which may be collected over warm water; it is highly inflammable, and of agreeable ethereal odour.

LACTIC ACID.

This acid exists in many animal fluids, especially in sour milk, and is also found in several vegetables. It is best obtained from the juice of the beet-root, previously fermented and evaporated to the consistence of a syrup. Alchol is added, which precipitates much vegetable matter, and dissolves the lactic acid. The alcoholic extract is re-dissolved in water, and the solution further purified by the addition of the carbonate of zinc. By evaporating the fluid, the lactate of zinc is obtained in crystals. The lactate of zinc is deprived of its oxide by baryta; and, lastly, the lactate of baryta is decomposed by sulphuric acid. Pure lactic acid is thus obtained.

The salts of lactic acid are all soluble in water. Their only importance resides in their occasional presence in various animal secretions.

CITRIC ACID.

This is a very important article. It is the object of extensive manufacturing operations in Sicily, and other warm countries, and it is very likely to become an advantageous export from India.

The juice of limes or lemons is mixed with finely powdered chalk as long as there is any effervescence. An insoluble citrate of lime is formed, which, after being well washed with water, is decomposed by dilute sulphuric acid. Sulphate of lime is formed and citric acid dissolved, and crystallized by evaporation. 87 parts of dry citrate of lime, 49 parts of strong sulphuric acid, and 10 parts of water are the proportions required.

The citric acid crystallizes in large transparent prisms, of strong acid taste, and pleasant flavour. It is soluble in its own weight of cold, and half its weight of hot water.

This acid is much employed in calico-printing, and as a substitute for lemons. It always brings a high price, and meets a ready sale.

TARTARIC AND RACEMIC ACIDS.

The *Tartaric Acid* has been already described. Its most important salts have also been noticed in detail under the sections on *Antimony* and *Potash.*

The *Racemic Acid* occurs in the grapes of the Upper Rhine, along with the Tartaric. These two acids closely resemble each other in their properties, and are identical in composition.

BENZOIC ACID, OR OXIDE OF BENZULE.

This acid exists abundantly in the substance called "Gum Benzoin," or *lobán,* (لوبان) in the urine of children, and of most animals which feed on grass.

Fine benzoic acid may be prepared by heating the powdered *lobán* in an earthen vessel provided with a paper cover, in which the vapours of the acid sublime, and are condensed. A still better process is by boiling the *lobán* with carbonate of potash in a large quantity of water, and precipitating by muriatic acid. The benzoic acid is thrown down, and purified by sublimation.

This acid is of a sweet, agreeable taste, and fuses by heat, evolving a fragrant odour. The vapour condenses on cool surfaces in beautiful feathery crystals. It is soluble in alcohol and in 24 parts of boiling water, but scarcely at all in cold water. It is composed of 85.68 parts of carbon or 14 eq. 5 parts of hydrogen, or 5 eq., and 24 parts or 3 eq. of oxygen.

Some curious facts have recently been ascertained regarding the composition of this acid. When the bitter almond is compressed, a pure fixed oil is obtained : but if the almonds be distilled with water, a volatile poisonous oil passes over, which smells strongly of Prussic acid. By mixing this oil with a solution of potash and proto-chloride of iron, and again distilling, hydro-cyanic acid is removed. By a second distillation from lime the oil is obtained pure. It is a colourless volatile aromatic liquid; specific gravity 1.043. It is inflammable, dissolved by alcohol, but insoluble in water. When heated with hydrate of potassa, hydrogen is evolved, and benzoate of potassa formed. Exposed to the air or pure oxygen gas, crystallized benzoic acid is formed. These facts are explained by the researches of Liebig, who has shewn that the oil above described consists of an organic proximate principle, called *benzule*, and 1 eq. of hydrogen; and that benzoic acid is composed of 1 eq. of benzule and 1 eq. of oxygen. *Benzule* is a compound of 14 eq. carbon, 5 eq. hydrogen, and 2 eq. oxygen. The oil of bitter almonds is a hydroguret, the benzoic acid a protoxide of benzule.

The chloride, bromide, iodide, sulphuret, and cyanuret of benzule have been prepared by Liebig, the discoverer of those interesting compounds.

TANNIC ACID.

This acid occurs abundantly in gallnuts, myrobalons, catechu, kino, the leaves of the tea plant, the bark of the *rohan* tree, and in all astringent plants, in which it is generally associated with the gallic acid.

The best process for its preparation is that lately devised by Pelouze. The lower aperture of a long narrow glass vessel is closed by a piece of linen. On this is laid some gallnuts in fine powder, on which sulphuric ether is poured. The upper aperture is closed to prevent the evaporation of the ether, and the vessel is fixed in a bottle to receive the ether as it filters through the powder. The ether of the apothecaries usually contains a little water, which in this process combines with and dissolves the tannic acid, the solution collecting in the bottle as a dense layer below the etherial fluid. This is drawn off by distillation, and the tannic acid solution evaporated to dryness at a very gentle heat, when it is obtained as a spongy white mass. Gallnuts by this method will yield 55 per cent. of tannic acid.

When pure, this acid is colourless, inodorous, astringent, and soluble in water. The solution reddens litmus, and effervesces with the alkaline carbonates;—it strikes a deep blue colour with salts of the peroxide of iron, but does not affect the protosalts. In open vessels it absorbs oxygen gas, evolves an equal volume of carbonic acid, and deposits crystals of gallic acid. With gelatine (see that head) it forms a dense precipitate, insoluble in water. This is the basis of leather, being formed by the gelatine of the skins and the tannic acid of the astringent substances employed in tanning. When properly prepared, the precipitate of *tanno-gelatine*, as it is called, contains 54 per cent. of the acid.

Artificial Tannic acid is prepared by the action of nitric acid on charcoal. 100 grains of charcoal in fine powder are gently heated in an ounce of nitric acid, diluted with two ounces of water until the charcoal is dissolved. The solution is evaporated to dryness, and re-dissolved in water or alcohol. In the properties above described, it is identical with the natural acid.

GALLIC ACID.

This acid is always associated with, and is in all probability the product of, the oxidation of tannic acid. When a solution of tannic acid is exposed to the air for some months in a warm moist atmosphere, a yellow crystalline matter is deposited, chiefly composed of gallic acid. This tannic acid disappears and carbonic acid is emitted during this process. The impure gallic acid is rendered quite white, and may be obtained in crystals by being dissolved in boiling water, and the solution digested with animal charcoal, previously deprived of its phosphate of lime by dilute muriatic acid.

Gallic acid does not precipitate gelatine. In other respects, especially in its action on the persalts of iron, it agrees in its properties with the tannic acid.

By subliming gallic acid, crystals of different composition called the *pyrogallic* acid are obtained. If the gallic acid be suddenly heated to 480°, carbonic acid and water are disengaged, and a black matter like charcoal remains in the retort. This substance is soluble in alkalies, from which it is again separated by acids in black flakes. It is termed the *metagallic acid.* When neutralized with potassa, the solution gives *black* precipitates with the soluble salts of baryta, strontia, lime, and magnesia, and with the oxides of iron, zinc, copper, lead, and silver.

The *Igasuric*, *Meconic*, *Indigotic*, and *Carbazotic* acids are described in the sections on strychnine, opium, and indigo.

SECTION II.

VEGETABLE ALKALIES.

A great number of vegetable principles have been discovered possessed of strong alkaline properties. They restore the colour of reddened litmus paper, turn turmeric paper brown, and form crystalline salts with the acids. In several instances the alkali possesses in a very concentrated degree the properties of the plant from which it is procured. Thus opium yields morphia; from hemlock we obtain conein; both narcotics of great power. The cinchona bark affords the inestimable quinine, a specific remedy in intermittent fevers.

The vegetable alkalies may be either solid, such as morphia, quinine, brucea, &c.; or fluid, as conein. All contain 1 eq. of nitrogen, with variable proportions of other elements; they are decomposed by great heat, yielding ammonia as one of their products. In the plants which afford them they are in combination with peculiar acids, which render them soluble in water, in which they are generally insoluble. They are dissolved by boiling alcohol, which on cooling deposits them in the crystallized state.

The preparation of the solid vegetable alkalies is founded on the following general principles. A solution of the active principle of the plant is made by water acidulated with the acetic, muriatic, or sulphuric acids. This solution is filtered, and lime, potash, soda, magnesia or ammonia, added, which combines with the acid, and precipitates its vegetable alkaline base in a very impure state, mixed with oily, resinous, and colouring substances. To purify it from these, animal charcoal is often employed, and finally, by boiling the mixture in alcohol, crystals of the alkali are obtained as the solution cools.

In operating on vegetable substances which contain a volatile alkali, such as the seeds of hemlock, a mixture of the seed and caustic potash is distilled, and the active product obtained in the receiver.

OPIUM, AND ITS PROXIMATE PRINCIPLES.

To this important subject I propose to devote more space than it generally claims in elementary treatises on Chemistry. The place it holds as a source of enormous revenue, and an article of the highest commercial interest, induces me to treat of it in this detail; and I do so the more readily, from the opportunities I have enjoyed of becoming practically familiar with the subject, having held the appointment of assistant to the Opium Agency of Behar for a considerable period. Details relative to the cultivation and gathering of the drug do not of course fall within the object of this manual; moreover, on this department of the subject, a paper published by Dr. Butter in the Journal of the Asiatic Society, provides the most ample and interesting information. In this section, then, I propose to give, first, a sketch of the composition of opium; secondly, of the manipulations to which it is subjected in the Government Factory at Behar; thirdly, of the mode of assay by which its value is regulated; fourthly, an account of the exact analysis of the drug, and the composition of the varieties supplied by the subordinate agencies of Behar; and lastly, I shall describe the adulterations to which the opium is so extensively subjected, and the methods by which these adulterations may be recognized. The sketch thus given, will, I trust, prove of utility in this great revenue department, and contribute in some degree to the improvement of the drug as a medicinal agent.

Opium is a concrete juice, obtained by practising superficial incisions in the capsule of the poppy. It is composed essentially of three alkalies, morphia, codeia, and narceia, united with a peculiar acid, termed the meconic,—of two vegetable crystalline principles devoid of alkaline properties, and termed narcotine and meconin,—of gum, resin, colouring matter, ulmin, caoutchouc or the basis of Indian rubber,—of fixed oil and lignin, or woody fibre. It also contains saline and earthy matter, such as carbonate of lime, sulphate of soda, and oxide of iron. Before describing the analysis, I shall give a succinct description of each of these constituents of the drug.

MORPHIA occurs in brilliant colourless crystals which, microscopically examined, are usually in six-sided prisms, with summits having two sides. It is composed of carbon 34 eq., hydrogen 18 eq., nitrogen 1 eq., oxygen 6 eq., with 2 eq., of water of crystallization. It is insoluble in water, but dissolved copiously by acids, by an excess of alkalies, and by strong boiling alcohol, from which it is deposited in groups of fine crystals. When pure it is nearly tasteless, but when in solution in alcohol or acids it is intensely bitter. It is strongly alkaline in its action, and forms numerous neutral salts with the acids. Concentrated nitric acid gives a fine blood red stain to morphia, of the *purest* kind,—a fact for which I can vouch; though it is asserted in almost all works on chemistry, that the stain is only given to the impure alkali. Per-muriate of iron changes it to a deep blue colour.

The *Salts of Morphia* are prepared either by the direct mixture of acids and the alkali in equivalent proportions, or, are separated during the analysis of opium, as I shall immediately describe.

The *Sulphate of Morphia* crystallizes in bunches of needle-shaped crystals, containing 40.1 parts of acid, and 288 parts of morphia, with 6 eq. of water.

Muriate of Morphia is the most important of all the salts of this base. It produces all the good effects of opium without causing head-ache, constipation, or the other unpleasant symptoms so frequently occasioned by the crude drug or its tincture, laudanum. Its preparation is described at length in another page. It crystallizes in tufts of needle-shaped crystals; is very soluble in alcohol and water, and of very bitter taste. It is permanent in the air, invariably neutral, or composed of 1 eq. of acid and 1 eq. of alkali.

The *Acetate of Morphia*, was until very recently, the favorite medicinal preparation of the drug, but its use is now nearly superseded by the muriate. The acetate is liable to great varieties in its composition, is deliquescent in the air, is decomposed by water, and often produces violent headache when taken even in the most cautious doses.

Codeia. This alkali was discovered in opium in 1832. It exists but in trifling proportion, but is more abundant in the East Indian than in the Turkey or Persian drug. It occurs in colourless transparent crystals, fusible at 300° without decomposition. Water at 60° dissolves 1¼ per cent. 3.7 at 160°, and 5.9 at 212°. When more is present than boiling water can dissolve, the residue melts and runs in oily-looking globules at the bottom of the vessel. The solution is alkaline, and, like morphia, forms neutral salts with the acids, composed of 263 parts, or 1 eq. of codeia and 1 eq. of the acid. Its solubility in water distinguishes it from morphia. It is also soluble in boiling ether, insoluble in solutions of the alkalies, gives a precipitate with tincture of galls, and is not reddened by nitric acid, in all which properties it is essentially different from morphia. In its effects on animals codeia is first powerfully stimulant, frequently occasions convulsions and great excitement, and is an energetic narcotic.

Narceia is white and crystalline, inodorous, faintly bitter, fuses at 168°, is soluble in 375 times its weight of cold and 230 of boiling water, also in hot alcohol, but is insoluble in ether. It is decomposed by strong acids, but unites with them when much diluted. It is feebly alkaline. The solutions of its salts are blue when concentrated, but on adding water, the colour passes to violet and rose red, and lastly disappears.

Narcotine is very abundant in opium, especially in the East Indian, and consequently deserves much attention. It occurs in snow-white crystals resembling sulphate of quinine, and of peculiarly soft texture and lustrous aspect. They are very soluble in ether, insoluble in cold water, and are dissolved by oil, by dilute alcohol and acids. It forms definite compounds with the acids, but can scarcely be regarded as an alkali, for its compounds with the acids are decomposed, and the narcotine separated in the pure state, by ether. It is not possessed of narcotic properties, is insoluble in alkalies, is changed to bright yellow by nitric acid, but unaffected in colour by per-muriate of iron. When mixed with morphia and boiled in a solution of muriate of ammonia, the ammonia is expelled, the morphia unites with the muriatic acid forming the soluble muriate, and the narcotine is precipitated. By this process mixtures of these two principles can be separated from each other.

From some trials first made in Europe, and repeated on a very large scale in India, it appears that narcotine may be much relied on as a powerful febrifuge in the treatment of intermittent fever.

MECONIN is a very curious substance, but cannot be easily prepared. At common temperatures it is white, solid, inodorous, and of acrid taste. It begins to fuse at 190°, and is a clear liquid at 195°. At 311° it sublimes, and condenses on cooling into a white fatty-like substance. It is soluble in 18 parts of boiling and 266 of cold water, and is very soluble in alcohol, ether, and the essential oils, from which solutions it crystallizes in prisms. It is neither acid nor alkaline in its relations to test paper or acids.

When dissolved in dilute and cold sulphuric acid the solution is colourless, but on concentration it becomes blue, and is decomposed. On adding water a chesnut-coloured substance subsides, which is soluble in warm strong sulphuric acid, to which it gives a green tint, and in alcohol and ether which become a rose-red. Nitric acid dissolves meconin, a yellow solution being formed, which, on evaporation, affords long yellow crystals. *Meconin*, though rare in the Turkey, is comparatively abundant in Indian opium. Its effects on the animal economy have not been ascertained.

The MECONIC ACID is peculiar to opium, in which it exists in combination with the alkaline bases above-mentioned. Muriate of lime in solution is added to a solution of opium in cold water; a precipitate is obtained composed of impure meconate of lime. This is mixed with ten times its weight of water at 200°, and muriatic acid is added until the meconate of lime is dissolved. The solution is thus filtered, and on standing for some hours it deposits a salt containing 2 eq. of meconic acid and 1 eq. of lime, in long needle-shaped yellowish crystals. By re-dissolving these in hot and dilute muriatic acid as before, crystallized meconic acid is obtained. If it retains lime, on burning a little on a slip of platinum foil or talc, an earthy ash remains, in which case the solution in muriatic acid must be repeated.

The meconic acid in this state is still rather impure, and must be neutralized with potassa, and the neutral meconate again decomposed by muriatic acid. After this purification the acid is obtained in perfectly white scales, resembling particles of talc, of acid taste and properties, and very soluble in alcohol and water. When boiled in water carbonic acid is disengaged; the liquid assumes a brown colour, and a new compound, the meta-meconic acid, is formed.

When a solution of this acid is added to that of a persalt of iron, a rich red colour is produced. The test operates with such delicacy that it is advantageously resorted to for the detection of opium in cases of poisoning.

The RESIN of opium is very black, resembling pitch, hard and brittle, fusible at 120°, soluble in acids and precipitated by alkalies, also soluble in alcohol.

The GUM differs much from ordinary gum, and more resembles that called tragacanth or bassorine. It is insoluble in alcohol, in cold or hot water, but by long boiling in water is converted into a substance resembling common gum.

The COLOURING MATTER is chiefly composed of *ulmine*, a vegetable principle abundant in the barks of trees, in peat soils, and many other sources. Ulmine is formed whenever gallic acid is exposed to the air, as we often observe in opium, the outer surface of which speedily becomes black from the formation of this principle.

CAOUTCHOUC forms the greater portion of the insoluble matter remaining after all the soluble parts of opium have been removed by washing with water. It is fawn-coloured, ductile, and elastic, putrefies readily, is insoluble in water and alcohol, but is dissolved by the alkalies, by naphtha, and sulphuric ether. Although termed caoutchouc, it still differs materially from the substance commonly so named.

Lignine, or the basis of woody fibre, exists in opium to a considerable degree. It is insoluble in any of the fluids above-mentioned, and constitutes the bulk of the residue after all the preceding substances have been removed.

Lastly, a dense black, acrid, fixed *oil* is found in variable quantities in opium, occurring repeatedly in the course of analysis, as will be immediately shewn.

The preceding ingredients constitute opium in its purest state. Under peculiar circumstances it also contains a substance well known in the factories and among the Chinese, to which the name of "*afim ke pasewá*," or opium sweat, is usually given.

Pasewá. This is a black, shining, viscid liquid, resembling tar, of strong narcotic smell and acrid taste. It is often seen in globules on the surface of the opium jars as these are received from the agents of the growers; but it forms in greatest proportion on the surface of the immense masses of the drug stored in tanks in the Government factories. The natives regard it as the "*Ján*," or essence of the drug, and it is said the Chinese are partial to its flavour. It has been the source of much difference of opinion in the establishment,—many supposing it to be quite a concentration of all the good qualities of the opium; others, on the contrary, regarding it as extremely detrimental. On analysis I have found it to contain all the principles of opium above enumerated; the caoutchouc and lignine being in much smaller proportion, the resin and oil in great excess, and the alkalies very scanty.

Pasewá imparts a black glistening aspect to the opium in which it occurs. I believe its presence to be injurious, more because it serves as a very convenient cover for frauds and adulteration, than from any intrinsically bad qualities it can possess. It originates, no doubt, in the incipient decomposition the drug undergoes by fermentation, by which its lignine and caoutchouc become soluble in water.

EXAMINATION OF OPIUM AT THE BEHAR FACTORY.

The reception of opium at the Government factories commences with the hot season, and terminates late in the rains. The drug generally arrives in batches or *chelâns* of several jars, the joint production of one *zillah* or its subordinate *kotés* or districts. The jars contain from twenty seers to one maund, and it is no uncommon event to have five hundred of these paraded in the morning for the inspection of the Opium Agent and his assistants. The first examination, and the resulting classification, are very simple. The examiners thrust a slit bambu into the contents of the jar, and judge from experience of the state of consistence, flavour, and colour of the specimen. Marks are chalked on the jar according to the degree of each of these qualities from 1.1.1. to 4.4.4. inclusive.

Opium of the first class is of a fine chesnut colour, aromatic smell, and dense consistence. It is moderately ductile, and, when the mass is torn, breaks with a deeply notched fracture, with sharp needle-like fibres, translucent and ruby-red at the edges. It is readily broken down under distilled water, and the solution at first filters of a fine sherry colour, which, however, rapidly darkens. 100 grains of this opium will yield to cold distilled water an extract of from 35 to 45 grains. The extract is a deep brown colour, and very rapidly attracts moisture from the air. If 100 grains of this opium be evaporated at 212°, it loses from 20 to 28 per cent. of water, giving a consistence of from 80 to 72, the standard of the factory.

The second class of opium is of darker colour, less agreeable smell, softer texture, and often shews black specks and globules of *pasewá* on its surface and in its texture. It draws out to greater length, but breaks with a more even fracture. Its consistence ranges from 65 to 70°, and it yields an extract averaging from 27 to 35 per cent.

The third class is black, pasty, of very heavy smell, drops from the examining rod, gives off from 40 to 50 per cent. of moisture on evaporation, but, owing to the great quantity of *pasewá* it contains, often gives a far greater per centage of extract than either of the two preceding classes. The extract is very dark,and deliquesces rapidly.

The last class comprises all that is too bad to be used in the manufacture of the balls. It is of all colours, from deep black to bright brown, and of all degrees of consistence, from fluidity to a solid texture.

After the cursory examination thus described, a portion of opium is taken from each jar of each *chelán* and mixed together, and from this mass three specimens of 100 grains each are accurately weighed, and evaporated to dryness on metallic tables heated by steam to 200°. When dry, the residue is weighed in presence of the native agents or gomáshtas by the first assistant; the weight indicates the consistence. All specimens above 70 receive a corresponding premium in the price paid: all below that number lose in proportion. The amount of extract is taken at the same time. On these data the officers of the factory proceed in sorting the jars for mixture in great tanks, into which they are all emptied. The jars are then washed, and the washings with the opium of the fourth class are used for *lewá* or paste to agglutinate the covering of petals used in making up the balls.

As the receiving season draws to a close, the opium is gradually removed from the tanks and cisterns, and exposed to the air in shallow wooden frames, until by spontaneous evaporation it becomes of the required consistence, from 69 to 70. In this state it is delivered to the cake-makers. Each cake must be of a certain weight,—the envelope of petals and *lewá* included; and it is surprising to see the dexterity and precision with which the workmen *snatch* the exact quantity required from the large dishes at their side, seldom erring more than a drachm weight in a ball of four pounds. The balls of each day's manufacture are carefully inspected the following morning, and re-opened and adjusted if required. Finally, they are stored in a large airy turret to undergo thorough ventilation and drying of the envelope.

A certain quantity of opium of the first class is annually prepared with more care for the use of the Medical service,—for presents to some Native potentates, and to the priests of a few favoured temples. An inferior but still very good kind is issued on the requisition of the *zillah* authorities, under the name of *ábkári* opium, to the licensed drug retailers of the bázárs.

ANALYSIS OF THE DRUG.

The annual official reports being simply required to state the amount of morphia and extract, and to give a general account of the physical qualities of the article, comparatively little attention is usually given to its exact chemical analysis. In proof of this, I may refer to the papers on Bombay opium published in the Transactions of the Medical and Physical Society, in which even the principle *narcotine* is not at all mentioned,—and to the records of the Behar Opium Agency, in none of which is any *exact* analysis recorded. Of a multitude of specimens marked *morphia*, which I received on assuming charge of the factory, few contained less than 30, many 50 per cent. of *narcotine* and other substances. These in exact returns were perhaps unavoidable, under the defective state of the laboratory, and the want of a sufficient number of practical assistants competent to manipulate analyses under the superintendence of the first assistant. But as practical native chemists can now be obtained at very moderate salaries, these defects, if they still exist, will doubtless meet an early remedy.

During my employment in this department I made a very extensive series of analyses of the opium furnished by each of the zillahs composing the Behar division. In the hope that these may prove of some utility, I append the processes employed, and a tabular view of the results obtained.

In the subjoined analysis either of the following modes of examination was adopted. The first is the quickest in its manipulation. The second has the advantage of supplying directly a fine muriate of morphia for medical use.

1st Process. A quantity of opium (I usually operated on a seer) is accurately weighed, and well rubbed with the hands under distilled water, until it is thoroughly broken down into a thin fluid. It is then filtered through *Naipál paper,* a texture of the greatest value in vegetable analysis, as it permits very rapid filtration, and is so strong that it may be twisted while wet, like linen or calico. The washing is continued until the filtered liquor gives no precipitate with ammonia, and the water solution is then evaporated to dryness on a water bath, and marked A. 1. The solid exhausted marc remaining on the filter is marked A. 2.

By this step a volatile acid with which the narcotine formed a soluble compound is expelled; so on redissolving the watery extract in distilled water, a black gritty crystalline powder remains. This is collected on a muslin filter, and boiled in water and filtered, and the solution which contains *meconin* evaporated to dryness. As the evaporation proceeds, globules of oily appearance collect at the botton of the capsule, and on cooling crystals of *meconin* of a rosy tint are obtained

The residue of the black powder is then boiled with strong alcohol and filtered. On cooling an abundance of snow-white crystals of *narcotine* is deposited.

To the solution of the watery extract (A. 1) liquid ammonia is gradually added. The first portions separate a great quantity of the *black resin,* which rises to the surface, or concretes on the bottom and sides of the vessels, and should be removed with a spoon and by decanting the fluid. This resin, though at first soft, rapidly hardens and becomes a pitch-black colour and consistence. When this has ceased to separate, ammonia is added more freely, and *the solution heated to nearly* 200°. This precipitates all the *morphia* in a crystalline powder, varying in colour from light fawn to that of dark clay, according to the quality of the opium under examination, and the care bestowed in the removal of the black resin in the previous step. The morphia is purified by washing it first with a little weak alcohol, and then dissolving in boiling alcohol as much as it will take up. The solution is filtered, and set aside in a tranquil place, and in 24 hours a large crop of very fine white crystals is procured. The solution evaporated still further, yields additional crystals of an inferior colour.

The watery solution of the extract A. 1, thus freed of morphia, still contains meconic acid and ammonia, codeia, narceia, gum, and colouring matter. To separate the meconic acid, add a solution of muriate of lime; a precipitate of meconate of lime is procured, which, when treated with muriatic acid, in the mode described under the head of meconic acid, yields very large crystals of bi-meconate of lime. From this the pure acid is prepared according to the directions already given.

It is almost useless to look for *codeia* or *narceia*, owing to their minute proportion, in the fluid, by this process. The *gum* may be precipitated by strong alcohol, but it is seldom desirable to take the trouble of this step.

The solid mass A. 2 consists chiefly of oil, narcotine, caoutchouc, resin, and woody fibre. It should be first boiled in water acidulated with muriatic acid. Muriate of narcotine is dissolved out, and the narcotine may be separated from this by ammonia. The muriatic acid solution is generally of a pretty rose colour, owing to the presence of traces of narceia, which have the property of communicating this tint to their dilute solutions.

The remaining solid mass is to be divided into very small portions, and allowed to rest in contact with a pretty strong solution of ammonia for 24 hours. This dissolves the oil and resin. The solution is decanted, and the solid mass marked A. 3. By cautiously adding an acid much diluted to this solution, the oil separates in globules which rise to the surface of the fluid, and the resin collects in dense clotted flakes, readily separated from the oil.

The mass A. 3 contains little but caoutchouc and woody fibre. The former may be removed by digestion with naphtha or sulphuric ether, and is obtained as a ductile mass on evaporating to dryness. The woody fibre, or *lignin,* now remains, and is characterized by its insolubility in alcohol, water, ether, or naphtha, and its fibrous thready texture.

In the preceding analysis I have taken no notice of the ulmine, which is so intimately associated with the colouring matter that they may be classed under one head, as the general residue of the evaporation of the solution of A. 1, after the removal of its morphia and meconic acid, deducting of course any saline or earthy matter which the incineration of a portion of the mass may shew to be present.

Lastly, 100 grains of the opium examined are incinerated in a platinum crucible; the residue when heated until its black colour disappears, gives the amount of saline and earthy matter which the opium contains.

2nd Process. This is directed chiefly to the procural of the muriate of morphia. The first steps of washing and separation of the meconin and narcotine are the same in both. The solution of the watery extract A. 1, is precipitated by muriate of lime, and the precipitate removed by filtration. The filtered liquid is next rendered neutral by adding some powdered chalk, then evaporated to the consistence of a syrup, and set aside. In 24 hours it becomes a crystalline mass, which must be compressed between numerous folds of Nipâl paper and coarse cloth. The crystals of muriate of morphia are purified by digestion with animal charcoal and water, and by three or four successive solutions in, and crystallizations from, hot water. The salt is then dried at 150°. It still contains codeia:

and is indeed the preparation from which this substance is obtained.

By adding ammonia to the muriate, all the morphia is precipitated, and the muriate of ammonia and *codeia* remains dissolved. On evaporating this nearly to dryness and adding a solution of pure potash, the codeia is precipitated in flakes, which crystallize from a hot alcoholic solution.

The remaining steps accord with those described in the first process. The alkali *narceia* can only be separated by operating on a much larger quantity of opium than can be properly sacrificed in a public establishment.

Many other processes have been recommended from time to time for the examination of opium. Boiling the solution of crude opium in magnesia was the method usually adopted in the Behâr factory. A solid precipitate was formed, containing meconate of magnesia, narcotine, and morphia, and this when boiled in spirit gave crystals termed *morphia* in the official reports, but which of course, were a mixture of morphia and narcotine. By using the solution of the watery extract A. 1, in the first process I recommend, the narcotine is however separated, and magnesia instead of ammonia may then be used to separate the morphia. The method is, however, practically inconvenient, and the long boiling it requires highly objectionable, because this tends to decompose the alkaline bases of the drug, and diminish the quantity of morphia which should be obtained.

Since the publication of the first edition, a large demand has arisen for narcotine, in consequence of the experiments I instituted on its remarkable febrifuge properties. I therefore append the details of a process more expeditious and economical than either of those above described, and by which the narcotine is obtained perfectly free from morphia, a matter of much importance.

Take 2 lbs. of good opium and break this down into pulp by the hand, with one gallon of spirit, sp. gr. 835°. Strain through cloth, adding a second gallon of spirit to the matter on the filter. The spirit dissolves the salts of morphia and narcotine. Add strong ammonia gradually till the liquid smells of the ammonia, and then distil without delay from an ordinary alembic, till two-thirds of the spirit are recovered. During the boiling, the ammonia decomposes the salt of narcotine, and that principle is separated; but as compounds of ammonia are themselves decomposed by morphia at a boiling temperature, the morphia remains in solution in the watery liquid in the still. Draw this off while hot, and allow it to stand for twelve hours. An abundant mass of dark brown crystals is obtained, consisting of narcotine, meconate of ammonia, and resin.

To purify these crystals, wash well with rain water. This dissolves the meconate of ammonia. Then wash with water acidulated with muriatic acid, and continue this till the solution ceases to taste bitter. The narcotine is thus dissolved, and the resin left; strain; add ammonia to the solution of muriate of narcotine, and this principle is deposited in snow-white curdy masses, quite pure, and only needing pressure and drying to be fit for use.

The liquid from which the first impure mass of crystals had been obtained, contains the morphia. Dilute it freely with water to separate resin; strain, concentrate, and add ammonia, crude morphia is precipitated, and may be purified by washing with weak spirit, and crystallization from boiling alcohol.

The muriate of lime process previously described, may be used with the morphia solution, instead of that now described.

Two pounds of good opium should yield by this process one ounce of narcotine, and a little more than one ounce of muriate of morphia. If the morphia be not desired in the separate state, the liquor of the still, after depositing narcotine, may be reunited by rubbing with the mass of solid matter left on the strainer. An opium is thus obtained, possessing all the *narcotic* properties of the drug, and very nearly equal in value in the Bengal markets to that sold as Abkári opium.

By this process narcotine can be prepared for less than eight annas the ounce, reckoning the sale of the morphia, or of the re-made opium as part of the proceeds. Muriate of morphia in England is worth at least fifteen shillings the ounce.

Analysis of 14 *specimens of Opium of* 5000 *grains each.*

Denomination.	Consistence.	Extract.	Colour of extract.	Residuum of filtered extract, A. 1.	Precipitated from extract by ammonia.	Pure morphia per cent.	Narcotine per cent.	Codeia in 5,000 grs.	Meconic acid.	Meconine in 5,000 grs.	Lignine per cent.	Oil per cent.	Resin per cent.	Caoutchouc.	Earthy and saline matters.
Average of manufacture, 1834,…………	71	44	Earthy red,………	49 gs.	212	3	2¼	25 gs.	Averaged from 5 to 7 per cent.	8	13	Averaged from 2 to 4 per cent.	Averaged from 11 to 26 per cent.	From 6 to 10 per cent.	3¾
——1835,…………	71	42	Fawn,………………	45.25	217	3	2	20 gs.		9	12				3¾
Behár Division, do.	76	40	Earthy red,………	49	198	2½	1¾	5		10	14				3¾
Sarun do.………………	77	39	Lighter than Behár, ………………	106	286	2½	1¾	…		a trace	16				3¾
Sháhábád ditto,………	76	40	Dark earthy red,	84	48	½	¾	…		…	11				3¾
Tirhut ditto, …………	79	38	Ditto ditto,………	46	326	2½	1	…		5 gs.	13				3¾
Patna ditto,…………	76	34	Dark clay,………	58	337	2	1	…		…	12				3¾
Bhágulpur ditto,……	75	46	Earthy red,………	45	375	3½	2½	11		10	9				3¾
Purneah ditto,………	77	40	Light brown,……	115	232	2	2	…		…	11				3¾
Házáríbágh ditto,……	77	47	Light fawn,………	54	330	4½	4	21		11	8				3¾
Malwah of 1829,…….	89	57	Ditto ditto,………	28.25	340	4¾	5½	25		9	7				3
Patna Garden Opium, 1833,…………………	87	50	Light brown,……	49	656	10¾	6	20		14	8				3¼
Dinájpur ditto,………	79	45	Earthy red,………	66	270	1¾	1	…		…	14				4
Benáres, 1835,………	71	44	Light brown,……	47	230	3¼	2	11		7	12				3¾
Pasewá from Sarun Opium, ………………	64	50	Deep black,……	150	354	½	1¼	…	2 per cent.	…	2				3

The analysis of the Garden opium is very remarkable. From 40 lbs. of Smyrna opium of the finest quality, M. Couerbe obtained 1 oz. of meconine, 1½ oz. codeine, ⅓ oz. of narceine, and of morphine 50 ozs. or rather more than 10 per cent. In several experiments recently described by Professor Christison in his letter to M. Guibourt, (*Journal de Pharmacie, October* 1835,) the Malwa opium gave 9½ per cent. of muriate of morphine, while in the hands of Mr. Duncan, Turkey opium afforded 10 per cent. of that salt. The best opium grown in Egypt yields 10 and a fraction per cent. From one very fine and dry specimen of the Smyrna drug, Dr. Christison obtained 14 per cent. of muriate of morphia. In all these cases the salt was rendered snow-white, and dried at 140° before weighing. 10 parts of muriate of morphia correspond to 9½ of crystallized morphia.

The specimen of garden opium I examined was, perhaps the finest which ever came under chemical analysis. The poppies were irrigated three times during the season, and no manure employed. The results deserve much attention. As we can grow in Bengal, at an insignificant expense, such opium as that I have described, it would be expedient to devote a few acres of ground in the vicinity of one of the factories to the cultivation of opium for the supply of the Medical Store Department. The opium now furnished is unquestionably good, (see its analysis under the head of "division, Hazaribagh,") but its quality may be rendered doubly fine, indeed superior to any opium in commerce, by the measure now recommended.

It is not, however, for the morphia or its compounds that the Chinese value the drug. The narcotine, codeine, and resin are more probably the stimulating agents which they prize, and which are sufficiently abundant in the average of the manufacture.*

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* I allow this passage to remain, merely to mark more prominently my avowal of its incorrectness. Subsequent experiments have shewn that it is for the *morphia* the Chinese esteem the opium.

ADULTERATIONS OF OPIUM.

The adulterations of opium are very numerous, and executed with great skill by the rayots themselves, their gomáshtas, and the native police functionaries employed in suppressing contraband traffic in the drug.

The substances chiefly employed are the starchy extract of pease or grain. The juice of the wood-apple *(bel)*, or quince *(Ægle marmelos)*, the extracts of several mucilaginous seeds, resin or dammer, catechu, clay, the boiled extract of the poppy plant, bháng, the juices of the *datura*, and of tobacco.

The physical qualities of the drug sufficiently indicate, to an experienced examiner, the general fact of adulteration. The smell of such opium is usually very unpleasant, or even offensive; its aspect smooth, and texture pasty or altogether incoherent. The mould which forms on its surface is black, red, or bright yellow, instead of the smooth white characteristic of the best opium. Still these marks are far from being unexceptionable. So skilfully, indeed, are the adulterations occasionally managed, that one of the oldest and best of the native *parakaiyás* (examiners) was once so deceived that he pronounced the counterfeit opium to be superior to a good specimen of the drug before him at the same moment.

The adulteration with starch and catechu is at the same time the most likely to mislead the examiner, and that the most easily detected. With the solution of a few grains of such opium in hot water, and allowed to cool, the tincture of iodine gives a dark blue precipitate. Catechu is detected in the same solution by the addition of a solution of glue or isinglass (gelatine). Opium contains gallic acid but no tannic acid, whereas catechu contains both, and with the last the gelatine gives a copious precipitate.

The mucilaginous extracts of *bel*, *tal-makannah*, &c. are detected by making a solution of the suspected drug in hot water

—filtering, concentrating the solution, and adding alcohol, which occasions a copious precipitate of gum, perfectly soluble in hot water. In solutions of pure opium the precipitate is scanty, and difficultly dissolved even by boiling water.

Resin or dammer is at once recognized by breaking the specimen down under water; the opium is diffused in soft flakes through the fluid. The resin collects in hard gritty particles at the bottom of the vessel, while the natural resin of opium is dissolved.

Clay is found by washing or by incineration. Good opium never yields more than 4 per cent. of saline or earthy matter. Any excess indicates adulteration.

The *narcotic juices* of the *datura* and *tobacco* are not susceptible of detection by chemical analysis, but their presence is at once inferred from their peculiar and offensive smell, exactly that of a Bengâli huqqa of the worst kind.

PRESENCE OF INDIGO IN THE OPIUM OF 1834.

I was led to the observation of this remarkable and interesting fact in the course of the analyses above described. In filtering the alcoholic solution of the black *narcotine* powder, obtained in the first step of the process on the specimen of "provision opium" for 1834, I was surprised to see the liquid passing of a deep green colour. The filter was stained blue at the edges, and an insoluble black powder remained, which, when treated with sulphuric acid, gave a blue solution. This solution was turned green by alkalies and by the proto-sulphate of iron; was bleached by chlorine, nitric acid, the nitrates, and per-chloride of iron. It gave a blue dye to paper and muslin, and, in short, by a multitude of experiments, the colour was found to depend on the presence of indigo in the drug.

The experiments were immediately repeated on a great number of specimens of the opium of that year, and with the same results, and immediate measures were taken to ascertain the amount of indigo present. The most accurate analysis, however, could not detect more than ¼ per cent. in the masses analysed. On pursuing the inquiry, it was found that while indigo could readily be detected in the mass of the drug, obtained from the Sarun, Tirhut, and Shahabad districts, and in the Sarun *pasewá*, the opium and *pasewá* of all the other zillahs did not give the least trace of that substance. Neither could it be found in the Benares opium of that year. Faint indications of this colouring principle were given by the provision of 1835; and it was found unequivocally, but in the same minute amount, in the Sarun opium and *pasewá* of the same season.

The exceedingly small portion of indigo present at once precludes the idea of its being the result of adulteration, or even of accidental admixture, and also renders the circumstance quite immaterial with reference to the value of the opium of the year in question. I have no doubt but that the indigo was derived from the *seth*, or spent indigo plant, with which the opium rayots manure their land in the districts mentioned. Indigo can readily be found in soils thus prepared, and being dissolved by the alkali of the *seth*, finds its way into the circulation of the poppy.

The subject is curious in a chemical point of view, and is not without its interest with reference to vegetable physiology. But I must distinctly repeat, that it no more affects the value of the opium in the question than the 3½ per cent. of earthy matter invariably present in all opium, can be considered as a fraudulent mixture of sand and clay.

There are many interesting details relative to the statistics of the opium factory of Behár, on which I would gladly enter, were these pages suited to the subject. I append a table shewing the quantity of opium received from each subordinate zillah in the year of my service in the department.

Total quantity of Opium received from each District, during the Season of 1835.

	Maunds.	Seers.	Chts.
Patna District,	2168	15	7½
Behár ditto,	2887	35	9½
Sarun ditto,	5539	18	4½
Sháhábád ditto,	3457	20	6¼
Tirhút ditto,	2489	28	14¾
Bhagulpur ditto,	617	31	11
Hazáribágh ditto,	48	4	4½
Rajeshye ditto,	—	22	4½
Purniah ditto,	318	14	5¼
Total maunds of 82 Sicca weight,	17527	31	3¾

One of the most extraordinary features in this vast establishment is presented by the opium tanks, in some of which at least 1000 cubic feet of opium are accumulated in one mass. Though exposed to a damp atmosphere, at the mean temperature of 90°. still no putrefactive fermentation takes place. It is remarkable, too, that though the smell of opium can be recognized half a mile from the factory, and though among the multitude of men and boys there employed, there are necessarily many regular opium eaters, still the people are all healthy, active, and robust to an unusual degree, and some of the oldest men in and about Patna are workmen of the establishment, and have been engaged in its duties for many years.

CINCHONIA AND QUINIA.

The celebrated Peruvian bark owes its medicinal efficacy to the presence of these two alkalies, especially the latter. Both are contained in the *red* bark; cinchonia alone exists in the *pale,* and quinia in the *yellow* variety.

The bark is reduced to coarse powder, and digested in hot water acidulated with muriatic acid. The solution is filtered, evaporated to the consistence of a very thin syrup, and slaked lime added in small portions until the liquid is alkaline. The quinia or cinchonia is thus precipitated, and when collected is dried and dissolved in hot alcohol, from which it crystallizes as the solution cools. 1 lb of yellow bark gives about 80 grains of quinia, or 1.4 per cent.

Quinine is very soluble in alcohol; its solution is intensely bitter. It crystallizes with difficulty, but with the acids forms highly crystalline compounds. Of these the most important is the

Di-Sulphate of Quinine, which crystallizes in fine feathery needles, composed of 329 parts or 2 eq. of quinine, 40, or 1 eq. of sulphuric acid, and 90, or 10 eq. of water. It is prepared by dissolving the impure quinine of the first process in dilute sulphuric acid. The adulterations of sulphate of quinine, whether fraudulent or accidental, are very numerous. Dr. Turner enumerates water, gum, sugar, starch, some ammoniacal salts, and acicular sulphate of lime, as the usual admixtures. Water is detected by drying the specimen at 212°, which should lose no more than 10 per cent. Sugar is found by dissolving the salt in water, precipitating by carbonate of potash, evaporating to dryness, and treating the residue with alcohol. This separates the sugar, which may be recognized by its taste. Gum and starch are found when the impure salt is acted on by strong alcohol, in which it is dissolved, and these substances left. Ammoniacal salts are detected by the strong odour of ammonia evolved on the addition of potash or lime. Sulphate of lime remains when a portion of the salt is heated to redness. Besides these, there are several other adulterations to which Dr. Turner does not allude. Of these, benzoic acid, and the crystals which are deposited by a solution of spermaceti in hot alcohol, are the most frequent, and apt to deceive. The former is detected by heating the salt on a watch glass covered with a cone of paper, when the benzoic acid sublimes. The latter forms an oily globule when thrown into boiling water, and on cooling concretes into a waxy crystalline mass.

STRYCHNIA AND BRUCINE.

The formidable poison Strychnia exists abundantly in the nut, and scantily in the bark of the Nux Vomica tree, *(Kuchilá)* which is common in several parts of Bengal. It is best obtained by reducing the nut to coarse powder, acting on this with cold water, evaporating the solution, and adding alcohol to precipitate the gum which it contains. The residue consists of strychnia combined with the igasuric acid. This is redissolved in cold water, filtered, heated, and the alkali precipitated by lime-water, and then dissolved in boiling alcohol, from which it crystallizes in small four-sided prisms. It requires 6,000 parts of cold, and 2,500 of hot water for its solution, and still these watery infusions are intensely bitter. With acids it forms neutral salts. With the nitric acid it gives a red colour, resembling that produced with morphine.

Strychnia is a poison of great energy, and always proves fatal by causing lock-jaw and tetanic convulsions. One quarter of a grain thrust into a wound killed a wild boar in ten minutes. Still from these powerful properties it has been found valuable in very minute doses as a remedy in palsy, and several other nervous and muscular affections.

BRUCEA.

This alkali was discovered several years since in a bark, which was supposed to be that of the *Brucea anti-dysenterica*, and which was often called the false angustura from its having been used to adulterate the genuine angustura bark. I have recently shewn, however, (see the *Quarterly Journal of the Medical Society of Calcutta*, No. 1,) that the bark in question is that of the *Nux Vomica* tree, the *Kuchila ká chilká* of the Bengál bázárs. It is remarkable that this bark should have been the cause of several singular errors. In South America it has been mistaken for the angustura; in Europe for the brucea; and in India, very lately, for the *Rohun*, (*Swietenia febrifuga;*) though from all of these barks it is widely different in its physical and chemical properties.

We can at once recognize the true *kuchilá* bark in the bazars, by its being covered with a fine rust-coloured exuberance, which is turned grass-green by nitric acid, while the inner surface of the bark is changed to a bright red by the same reagent.

The process which I subjoin for the preparation of this alkali, is that originally devised by Pelletier and Caventou for its extraction from the supposed false angustura. I have repeated it on the nux vomica bark and found it extremely productive.

To obtain *brucine*, the bark of the nux vomica tree is first treated with sulphuric ether to get rid of a fatty matter which it contains. It is then subjected to the action of alcohol. The alcoholic solutions are evaporated to dryness, the dry residue is dissolved in water, and the solution mixed with sub-acetate of lead, which throws down the greatest part of the colouring matter. The excess of lead is got rid of by a current of sulphuretted hydrogen gas. By this method the liquid is rendered nearly, but not completely, colourless. The brucine is not precipitated by ammonia, and all attempts to procure it in a state of purity were long unsuccessful; at last the experimenters succeeded in the following manner: The brunce was saturated with oxalic acid, and the solution evaporated to dryness. The dry mass was digested in absolute alcohol, of the temperature of 32°, which dissolved the colouring matter, and left the oxalate of brucine in the state of a fine white powder. The oxalate, when treated with lime or magnesia, is decomposed, and the brucine disengaged. It was dissolved in boiling alcohol, and obtained in crystals by the slow evaporation of the liquid. Thus obtained in a state of purity, it possesses the following properties:—

Its crystals, when obtained by slow evaporation, are oblique prisms, the bases of which are parallelograms. When deposited from a saturated solution in boiling water by cooling, it is in bulky plates, somewhat similar to boracic acid in appearance. The alcoholic solutions are apt to deposit it in the form of mushrooms. In the last two states it is very bulky, retaining a great proportion of water, which may be forced out by compression. It then diminishes very much in volume.

Brucine is soluble in 500 times its weight of boiling water, and in 850 times its weight of cold water. The colouring matter with which it is united in the bark increases its solubility very much. Hence the difficulty of purifying it by crystallization.

Its taste is exceedingly bitter and acrid, and continues long in the mouth. When administered in doses of a few grains. it is poisonous, and acts upon animals in the same way as strychnine, but with much less energy.

It combines with the acids, and forms both neutral and bi-salts. Both of these sets of salts, but especially the latter, crystallize with facility.

Sulphate of Brucine.—Brucine dissolves readily in sulphuric acid, and is capable of forming with it a neutral salt. This salt crystallizes in long slender needles, which appear to be four-sided prisms, terminated by pyramids so fine that their shape could not be determined even by employing powerful magnifying glasses. It is very soluble in water, and somewhat soluble in alcohol.

No acid is capable of decomposing this salt, except strong nitric acid, which acts upon the brucine, and decomposes it, forming a fine red colour. It produces the same alteration of colour upon strychnine and morphia.

When brucine is digested in a still greater quantity of nitric acid, a fine red colour is also developed. The same phenomenon appears with strychnine, but the shade of colour is different. When either of these red liquids is heated, it becomes yellow. Protomuriate of tin dropped into the yellow liquid from strychnine occasions a dirty-brown precipitate, whereas in the yellow liquid from brucine, it strikes a very intense and beautiful purple.

The preceding account of Brucine is condensed from a very valuable article on the subject in the 15th vol. of the *Annals of Philosophy*, p. 311. It is unnecessary to cool the alcohol to the low degree mentioned, though it is desirable to reduce its temperature as much as can be economically effected by the use of saltpetre or sal-ammoniac.

The Sulphate of Brucine may be used with great advantage in the practice of medicine; and from several facts which have lately fallen under my observation, I believe it will often be found a very effectual substitute for sulphate of quinine, when given in doses of from half a grain to one grain in the treatment of intermittent, but not of remittent, fevers.

VERATRIA, EMETIA, ETC.

Veratria is the alkaline base of the seeds of the hellebore and the root of the colchicum. It is prepared by a modification of the preceding processes, and is found a very useful remedy, though requiring much caution in its administration.

Emetia has been extracted from ipecachuanha root. It is white and pulverulent, very bitter, forms salts with the acids, and is powerfully emetic.

Conein is prepared by distilling the seeds of the hemlock with caustic potassa. It is a limpid, alkaline, volatile liquid, which forms salts with the acids, and possesses the poisonous and medicinal properties of the hemlock in a most marked degree.

Aconitina is a powerful poison, prepared from various species of Aconite.

Solania has been obtained from the woody nightshade. **Picrotoxia** from the Cocculus Indicus. **Delphia** from the stavesacre; the liquid alkali **Nicotina** from tobacco; **Atropia** from belladonna and the mandrake. These substances do not require more minute notice.

SECTION III.

SUBSTANCES, THE OXYGEN AND HYDROGEN OF WHICH ARE IN THE SAME RATIO AS IN WATER.

SUGAR.

Sugar is a very common vegetable secretion, being formed in the juices and fruits of a multitude of plants, of which the sugar-cane, maple tree, and beet root give the most abundant products.

In the ordinary West Indian process the juice of the sugar-cane is boiled down at a moderate temperature, and during the boiling small quantities of lime-water are added, for the purpose of neutralizing the natural acid present in the cane, and which would impede the crystallization of the sugar. The lime-water also separates some resinous impurities previously dissolved by the acid, and which collect at the top of the boiler, and are easily removed. When reduced to a proper consistence, the syrup is run into coolers for its first crystallization and subsequently removed to perforated casks, which allow the uncrystallizable matters, called molasses and treacle, to percolate, and favour the drying of the sugar, which in this state is called raw, or muscovado sugar.

Raw sugar is purified by boiling it with the serum of blood, (albumen,) or the whites of eggs. The clarified juice is concentrated at a low heat, and received in conical earthen vessels, the apex lowest, and perforated to allow the fluid parts to drain. When dried, this constitutes refined sugar. In the evaporation the lower the heat the better the product. Mr. Howard's invention of boiling sugar in a vacuum, by removing the pressure of the atmosphere, effected a vast improvement in the refinery of this substance.

Pure sugar crystallizes in four or six-sided prisms, bevelled at the extremities.

The crystals are formed on threads fixed in the syrup, which is allowed to evaporate slowly; a small quantity of alcohol being added.

Sugar is soluble in its own weight of cold and in a very small proportion of hot water. It is soluble also in four times its weight of alcohol. It is decomposed and charred by the sulphuric, and converted into the oxalic acid by the nitric acid. The ultimate composition of sugar is stated by Prout to be carbon 42.85, hydrogen 6.35, oxygen 50.8.

Manna.—This is the concrete juice of some species of the ash tree, and contains a sweet principle termed *mannite*, which crystallizes in soft starry needles from a saturated alcoholic solution.

STARCH.

This is a very abundant proximate principle, being the chief constituent of most kinds of grain, of several roots, and many varieties of pease, &c. It can be procured in a pure state from flour, by enclosing a little in a muslin bag and pressing it between the fingers under water. The starch passes through as a very fine white powder. An adhesive white mass, resembling caoutchouc, remains within the muslin, and gum and sugar are dissolved by the water.

Starch is white, tasteless, and inodorous, insoluble in ether, alcohol, and cold water, but converted into a jelly by boiling water, in a large quantity of which it dissolves. Starch in a cold solution strikes a deep blue colour with iodine, which colour is bleached by boiling the mixture. When dry starch is heated to about 220°, it acquires a reddish tint, and becomes soluble in cold water. The same change is effected by boiling starch with water. The solution evaporated to dryness becomes a transparent horny mass, which is called *amidine.* If heated still further, its colour deepens, it becomes very soluble in water, and gives but a faint purple with iodine. In this state it much resembles gum, and under the name of British gum, is used in large quantities by calico-printers.

During the germination of seeds, starch is converted into sugar, a change which is also effected by frost, or by boiling in sulphuric acid diluted with twelve times its weight of water. No oxygen is absorbed from the air during the process, and the acid undergoes no alteration; still 100 parts of starch thus treated yielded 115 of sugar.

INDIAN ARROW ROOT is starch of the purest kind, and sago and tapioca are the same when first extracted, but are partially converted into *amidine* by the heat employed in the preparation. The dried tubers of several species of *Orchis* are called *Salep*, and consist chiefly of a modification of gum called *Bassorine.*

GUM.

Gum Arabic affords the best example of this principle, of which many varieties exist. It is colourless, transparent, and brittle, soluble in water, with which it makes a viscid solution called *mucilage.* It is insoluble in ether and alcohol. The solution is precipitated by sub-acetate of lead. Strong sulphuric acid chars and decomposes gum, and nitric acid converts it into the *mucic acid.*

LIGNIN.

Lignin, or woody fibre, is the most abundant principle in plants. It is prepared by digesting saw-dust successively in alcohol, water, and dilute muriatic acid. It is tasteless and inodorous. By alkalies it is converted into a soluble principle called *ulmine*. By strong sulphuric acid it is partially converted into sugar, and nitric acid changes it into the oxalic, nitric, and acetic acids.

SECTION IV.

OILS, RESINS, AND BITUMENS.

Oils are of two kinds, the fixed and the volatile. The composition of the fixed has been already described.

The essential or volatile oils are usually obtained by distillation from aromatic plants. The bark, flowers, &c. from which the oil is to be derived are distilled from a vessel containing water, and the product condensed in cooled receivers. These oils are insoluble in water, but dissolved by alcohol and the fixed oils. They are inflammable, and absorb oxygen from the atmosphere at common temperatures. Mixed with nitric acid, they often inflame. They dissolve sulphur and phosphorus, and unite with the alkalies, though with some difficulty, forming soapy compounds.

There are three leading groups of volatile oils. The first consists of the essence of turpentine and of lemons, which are pure carburets of hydrogen. The second contains carbon, hydrogen, and oxygen, and includes the volatile oils of anise, juniper, camomile, carraway, lavender, peppermint, rosemary, and the solid essence camphor. The oils of the third kind contain some other principle—for instance, the oil of mustard, in which sulphur can be detected in considerable quantities.

The essence of turpentine, also called *camphene*, and the essential salt of lemons, *citrene*, have been already described.

Camphor, or the protoxide of *camphene*, is obtained by sublimation from the camphor laurel tree, and exists in abundance in many other vegetables. It is soluble in alcohol, but insoluble in water, on the surface of which it floats. It is very volatile, fuses at 208°, and boils at 400°. When treated by nitric acid it forms an acid named the camphoric.

RESINS, CAOUTCHOUC, WAX, &c.

Resins are secreted by an infinite number of plants, and present many varieties in their physical properties of colour, taste, smell, &c. They do not conduct electricity, are fused by the application of heat, and burn with a yellow flame and dense smoke. They are soluble in the alkalies, in alcohol, ether, and the essential oils, but altogether insoluble in water. Melted with wax and oil, they form ointments and plasters, and with oil or alcohol they produce varnishes of different kinds. The most important resins are copal, mastic, sandarac, elemi, dragon's blood, and common resin, which is procured by distilling turpentine, and constitutes its solid residue.

The *Balsams* are compounds of resin and benzoic acid; some, like storax or benjamin, are solid; others, like the balsams of Tolu and Peru, are dense fluids.

Gum Resins are mixtures of resin, gum, essential oils, and extracts. The gum and extract are dissolved by water,—the resin and oil are taken up by alcohol. Hence a mixture of these liquids is their proper solvent. Aloes, scammony, and many other valuable medicines, are substances of this kind.

Caoutchouc, or Indian rubber, is the concrete juice of several trees of South American and Indian origin. When first drawn from the tree it is a milky liquid which soon coagulates, forming a white, soft, very ductile and highly elastic solid. It is inflammable, insoluble in water and alcohol, but is softened and sparingly dissolved by ether. It is soluble in the essential oils, ether, naphtha, cajeput oil, and in an oily liquid obtained by distilling caoutchouc itself. From all these solvents, except the essential oils, it is left on evaporation in its naturally elastic state. When softened by these re-agents, it is used to render cloth and other tissues water-proof. The manufacture of such articles has, within the last few years, grown into a most important branch of trade.

When *Caoutchouc* is carefully heated it melts, and at a higher temperature gives out 8-10ths of its weight of a very light volatile oil, called *caoutchoucine,* which dissolves caoutchouc, copal, and resins, and is hence of much value for the preparation of varnishes and water-proof cements.

Wax is produced by many vegetables, and is also secreted by the bee. It is generally of a light brown colour and peculiar odour, but is rendered inodorous and white by chlorine or by exposure in thin slices to moist air and light. Its specific gravity is 0.96. It fuses at 150°, and when inflamed, burns with a clear white light. It is insoluble in water, but is dissolved to a trifling degree by boiling alcohol and ether. It unites with the alkalies to form soaps, and in every proportion with the oils and resins. According to some chemists, two proximate principles may be found in wax,—one, *cerin,* is soluble—and the other, *myricin,* is insoluble in alcohol.

BITUMINOUS SUBSTANCES.

This class embraces the Bitumens, strictly so called, and pit-coal. The Bitumens include naphtha, petroleum, mineral tar, mineral pitch, and asphaltum.

Petroleum is a fluid thicker than naphtha, occuring in springs in many parts of the world, and found in much purity at Rangún. It contains an inflammable wax-like substance called Paraffine, which may be obtained in considerable quantities, but by a tedious and expensive process. *Asphaltum* is a brittle black solid, breaks like glass, fuses readily, and dissolves in naphtha, forming an excellent varnish.

TAR, AND ITS PROXIMATE PRINCIPLES.

During the heating of vegetable and animal matters in close vessels, a black viscid fluid called *tar* is distilled over, which contains water, acetic acid, naphtha, and occasionally ammonia, with several proximate principles very recently discovered by Dr. Reichenbach.

Paraffine is prepared by the distillation of wood tar. Three liquids are obtained, the heaviest of which contains this substance. On mixing this liquid with half its weight of sulphuric acid and boiling it, on cooling, the paraffine collects on the surface of the fluid, and may be removed and purified by solution in strong alcohol, from which it crystallizes on cooling.

Paraffine is white, tasteless, and inodorous, fuses at 111° and evaporates unchanged. It is very inflammable, burning with a bright white flame. It resists the action of acids, alkalies, and potassium. It unites with wax, and is dissolved by ether, naphtha, turpentine, and the oils.

Eupione is a limpid colourless liquid, tasteless and inodorous, spec. gr. 0.74; boils at 339°, insoluble in water, but dissolved by ether, turpentine, almond oil, and alcohol. 100 parts of Eupione dissolve in 33 of cold alcohol. It is most abundant in animal tar, from which it is prepared by distillation with sulphuric acid, and purification by cold alcohol.

Creosote. This substance has attracted much attention from the extraordinary medical properties it is said to possess. Although I am inclined to doubt its virtues, I still give the process for its preparation, published by *M. Koene* in the *Annales de Chimie*, and which is more economical, and of easier manipulation than the method given in Dr. Turner's work.

Coal tar is distilled from a retort provided with a long conducting tube led over a capsule containing a little water. The first product swims on the water, and may be thrown away. A fluid heavier than water soon collects, and as long as this liquid comes over, the distillation is continued. A solution of carbonate of potash is added to this liquid, to saturate some acid it contains, and which keeps the creosote in solution, and the mixture is again distilled. The resulting fluid is agitated for a few minutes with half an ounce of phosphoric acid to every twenty ounces of the oil, and then well washed with water. The water is separated, and distillation again had recourse to. The rectified oil is mixed with a solution of caustic potash, and allowed to cool. On saturating this with phosphoric acid, perfectly pure creosote rises to the surface of the liquid, in the proportion of 1¼ ounce to every pint of tar operated on.

Creosote is a transparent, colourless liquid; sp. gr. 1.037, of burning taste and odour like that of smoke, soluble in 80 parts of water, and in all proportions in alcohol, ether, and naphtha. With the alkalies and lime it forms compounds soluble in water, from which the creosote is separated by acids.

The exact composition of Creosote has not been ascertained.

Three other principles have been found in tar, and described by Reichenbach. They are called piccamar, capnomor, and pittacal, but their composition and properties are, as yet, but uncertainly known.

COAL.

Coal is divided by Dr. Thomson into four groups. The first is *caking* coal, the particles of which are softened by heat. The second is termed *splint* coal, from its splintery fracture. The *cherry* coal is slaty, hard, and very inflammable. The fourth kind is *cannel* coal, which is of compact structure, and on heating in close vessels yields an abundance of gas of fine quality. Coal is composed of carbon, oxygen, hydrogen, and nitrogen. The carbon remains in the retorts after distillation, and is called *coke*. The gaseous constituents form the several compounds already described under the head of coal gas.

Glance coal, or anthracite, is composed of carbon alone. It consequently burns without flame, and yields no volatile products.

SECTION V.

SPIRITUOUS AND ETHEREAL PRINCIPLES.

ALCOHOL AND ETHER.

The composition of these liquids with many of their properties has been described in other sections of this Manual.

ALCOHOL is the product of the vinous fermentation described under that head. It is prepared by distilling rum, whiskey, brandy, or any other spirit. The specific gravity of the product is about 0.835, and in this state it still contains a considerable quantity of water. This is removed by adding dry carbonate of potassa, caustic lime, or baryta, or chloride of calcium. The alkali or salt unites with the water, and collects at the bottom of the vessel, leaving very strong alcohol above. This spirit has the specific gravity of from 796° to 800°, and is called *absolute* alcohol.

Alcohol is a colourless, fragrant, and inflammable liquid, boils at 176°, and has never been frozen. It unites with water in every proportion. Equal weights of these fluids constitute the *proof-spirit* of the English excise, the density of which is 0.920 at 62°, Fahrt.

Alcohol has been lately shewn to enter into a series of definite compounds with several substances, especially the chlorides of calcium, magnesium, and zinc, and the nitrates of lime and magnesia. Nitrate of magnesia thus crystallizes with nine equivalents of alcohol. These compounds are called *alcoates.*

Sulphuric Ether. For the preparation and properties of this valuable fluid, see page 135. The changes which take place during the preparation, require additional notice here.

When the ingredients for preparing ether are mixed, and before heat is applied, if we add carbonate of baryta to the liquid, a portion of sulphate of baryta is thrown down, and a salt of baryta remains in solution, the acid of which is termed the *Sulpho-vinic acid.* This acid is shewn by conclusive experiments to be composed of sulphuric acid and alcohol. The sulpho-vinate of baryta occurs in crystals containing 1 eq. of water of crystallization, which is expelled by a heat of 122°. On increasing the temperature, *alcohol* is evolved, and sulphate of baryta remains. Free sulpho-vinic acid has not been obtained. Many chemists regard it as a species of salt formed by 2 eq. of sulphuric acid and 1 eq. of alcohol, the alcohol acting as the base. In this light the sulpho-vinate of baryta is a double salt, 1 eq. of acid being united with baryta, and 1 eq. with alcohol; being, in other words, a double sulphate of baryta and alcohol.

From the preceding facts, it is apparent that in the formation of ether, sulpho-vinic acid is first produced. When this is heated it is resolved into hydrated sulphuric acid and ether. The ether is volatilized and the hydrated acid remains, and may be employed to generate fresh quantities of ether by the addition of more spirit. In proof of this explanation of the formation of ether, Mr. Hennel found, that when strong sulphuric acid was heated with sulpho-vinate of potash, *ether* was disengaged; but by decomposing the same salt by dilute sulphuric acid, *alcohol* was formed.

Nitrous ether is prepared by mixing equal weights of alcohol and strong nitric acid. The acid must be added to the alcohol in very small quantities, allowing the mixture to cool after each addition. Extremely violent action takes place unless these precautions be observed. The mixture is next distilled at a gentle heat, and the product collected in Woolfe's apparatus.

Nitrous ether is a compound of 1 eq. of ether and 1 eq. of hypo-nitrous acid. During its formation, nitrous and nitric oxide, nitrogen, and carbonic acid gases are copiously disengaged. It is more volatile than the sulphuric ether, and is extremely inflammable. Its odour is peculiarly agreeable. Dissolved in alcohol, this ether forms the well-known and useful medicine called the "sweet spirits of nitre."

Where nitric acid cannot be procured, a mixture of alcohol, sulphuric acid, and nitrate of potash will form this product.

Several other ethers have been described, of which the most remarkable are the muriatic, hydriodic, phosphoric, acetic, and oxalic. They are not however, as yet applied in medicine or in the arts.

SECTION VI.

COLOURING MATTER, AND VARIOUS VEGETABLE PRINCIPLES.

The subject of this section is closely connected with animal as well as vegetable chemistry; some of the most remarkable and valuable colours, such as cochineal and lac-dye, being derived from the animal kingdom. Still it is more convenient to treat of the entire under the same head.

The simple colours, by a combination of which all the others are produced, are blue, red, yellow, and black.

Of these colours, several form with wool, silk, linen, and cotton, compounds insoluble in water. These are termed *substantive* colours. Others again are readily dissolved from these tissues by water, but the watery solution forms coloured and insoluble compounds with various oxides, such as alumina, the oxides of iron, lead, tin, &c. Hence if a fabric of any of these tissues be impregnated with a solution of the oxides in question, the colour is precipitated on the cloth with which it forms an insoluble compound. Dyes of this description are called *adjective* colours, and the intermediate agent is called the *basis* or *mordaunt*. The precipitates which solutions of the basis and the adjective colour form, are termed *lakes*. *Permanent* colours are those which, like indigo, quercitron, and some others, require no basis, but directly unite with cloth to form the insoluble compounds required. The subsequent experiments will illustrate plainly the meaning of these remarks.

If a few pieces of *stick-lac* be ground to powder, and washed with cold water, a fine red solution is obtained. This may be concentrated by evaporation, and it imparts a corresponding colour to bleached linen, calico, paper, &c. But the colour is at once removed by washing these fabrics in water. Here then the colour of the lac is *fugitive*, and in this state it cannot be used for the purposes of the dyer.

But if the solution of this colour be rendered alkaline by potassa, soda, or ammonia, and muriate of alumina or tin be added, the alkali precipitates the metallic oxide, and along with it the colouring matter is thrown down, forming a rich red deposit or *lake*, totally insoluble in water.

Now by a simple modification of this experiment, we can imitate one of the most remarkable processes of the dyer. If we steep a piece of cotton or woollen cloth in a solution of muriate of tin and then dry it, and if we subsequently immerse this prepared cloth in an alkaline solution of the lac red, the colouring matter is immediately precipitated in combination with the *basis*, the oxide of tin, and both uniting with the cloth, give it a brilliant red colour, which cannot be removed by water, and which, as it depends on the auxiliary action of the basis, is called an *adjective* colour.

I shall in the first place notice some colours of the *fugitive* kinds, which are of great importance to the practical chemist.

The *blue test-papers*, so frequently mentioned in the preceding pages, are generally prepared from the fermented juice of the litmus, or *Rocella tinctoria*, a plant abundant in several islands in the Mediterranean. A concentrated solution of the extract is prepared, and common printing paper is dipped in it, and subsequently dried. This paper is of a delicate blue colour, and is instantaneously turned red by even the weakest acids, and the blue tint is restored by alkalies of every kind.

A more convenient, and perhaps more generally useful *blue* test-paper is prepared from the *red* cabbage. When this is sliced and boiled in water, a *blue* solution is procured. When this is concentrated by evaporation, it may be used in the same manner as litmus for dyeing paper. The colour of such paper is rendered red by acids, and green by alkalies, while it is entirely unaffected by the neutral salts.

The red flowers of the Juba, *Hibiscus Rosasinensis* yield a blue juice which makes a good test-paper colour.

Yellow test-paper is another article of great utility in the laboratory, and is easily prepared by making a solution of turmeric in boiling spirit, and evaporating it to the consistence of a syrup. Papers dyed in this fluid are of a fine yellow, but are changed to a deep-brown by alkalies of every kind, and by the alkaline earths; the original yellow colour is restored by acids. But several neutral salts, and even the *boracic acid,* act on these papers like alkalies, and hence their utility, though very extensive, is occasionally questionable.

There are a multitude of flowers, seeds, roots, &c. which give blue, red, and yellow dyes of this fugitive kind. The petals of the passion flower and blue convolvulus, the juice of the Indian fig, and many other substances, might be cited as examples; but if we attempt to dye clothes with these colours, the dye is washed away by the first contact of water.

I shall next give a few examples of the permanent dyes, or those which requiring no basis at once form a compound insoluble in water, commencing with indigo, one of the most valuable and extraordinary of all vegetable productions.

THE BLUE PERMANENT DYES,—INDIGO.

It would be beyond the compass of this Manual to enter into a detailed description of the sources, cultivation, or manufacture of indigo in this country.

The *Indigo* of commerce consists of several ingredients, which may be separated by the following processes.

1st. If we digest finely powdered indigo in dilute sulphuric acid, filter, neutralize the solution with chalk, filter again, and evaporate the solution to dryness by acting on the residue with alcohol, a yellow transparent glutinous matter is obtained.

2nd. If to the indigo thus purified from gluten we add a very dilute solution of potash, a green liquid is obtained, which when heated with sulphuric acid, gives a black precipitate. By washing this with a dilute solution of carbonate of ammonia, a compound termed *indigo-brown* is formed.

3rd. A considerable portion of indigo remains after the first step of the second experiment. By boiling this in strong alcohol, a red solution is procured, which on evaporation deposits a dark powder, which forms with nitric acid a fine purple colour. This compound is termed the *indigo-red.*

4th. After acting on indigo by all the preceding processes the true colouring matter, or *indigo-blue,* is left. This sublimes at 550°, and condenses in long needle-shaped crystals, which are devoid of taste and odour, and insoluble in water, alkalies, or ether. Alcohol takes up just sufficient to acquire a blue tint. Strong sulphuric acid, especially the fuming variety, dissolves it quickly. The solution is a deep blue, and is called the *sulphate of indigo,* although the dye does not saturate the acid. Berzelius considers the compound to be a peculiar acid, which he names the *indigo-sulphuric.*

Indigo-blue is composed of carbon 45 eq., hydrogen 15 eq., nitrogen 3 eq., oxygen 6. It parts readily with a portion of its oxygen, and at the same time loses its colour and becomes soluble in alkalies, and finally in water, through their agency. Hydro-sulphuret of ammonia, of potash, or of lime, the protoxide salts of iron, the sulphuret of arsenic, and a multitude of similar substances effect this change, and a yellow solution is produced.

If to this yellow solution we gradually add dilute muriatic acid, a thick *white* precipitate falls, which continues colourless as long as all sources of oxygen be excluded. This substance may be procured in the dry state, and is called *Indigogen.* It is composed of carbon 45 eq., hydrogen 15 eq., nitrogen 3 eq., oxygen 4 eq., being two equivalents less of oxygen than Indigo-blue. On exposure, while moistened, to the air, it absorbs 11 per cent. of oxygen, and rapidly becomes blue, and the same change is rapidly effected by all agents rich in oxygen. To obtain this *white* indigo, a mixture of 1½ oz. of indigo, 2 of green sulphate of iron, 2½ of slaked lime, and 60 of boiled and distilled water are the best ingredients. They should be allowed to stand for twenty-four hours in a stoppered bottle, and the yellow solution mixed with dilute muriatic acid. The process is certain of success, if the vessels be filled with hydrogen gas instead of common air, in order to exclude oxygen altogether. This may be easily accomplished by mixing the ingredients in one of Woolfe's bottles, and passing a current of hydrogen gas through the entire from a mixture of zinc, sulphuric acid, and water in the first bottle.

These facts are of daily practical application in dyeing. Indigo is mixed in a vat with water, three times its weight of sulphate of iron, and an equal quantity of slaked lime. The lime precipitates the protoxide of iron; this deprives the indigo of its oxygen, and converts it into the white indigogen, which is dissolved by the unchanged lime, and a yellow solution is formed. When cloth is moistened with this fluid, it quickly becomes green, owing to the mixture of blue and yellow. Lastly, the fine blue colour is formed by the oxidation of the indigogen, which uniting with the cloth, forms a permanent substantive colour, insoluble in water.

Oxidized indigo is not soluble in alkalies, and consequently it is not bleached by soap. Prussian blue, (the cyanuret of iron,) on the contrary, is at once decomposed by alkalies, and peroxide of iron formed. Hence in all tissues which require washing in solutions of soap, the Prussian blue is almost useless, and certainly never can compete with its Indian prototype.

Indigotic Acid is prepared by boiling indigo in dilute nitric acid. It is deposited on cooling, boiled with oxide of lead, the solution filtered, decomposed by sulphuric acid, and filtered again while boiling. The acid crystallizes in long needles as the solution cools. It contains five times as much oxygen as indigo-blue.

Carbazotic Acid. By boiling indigo in strong nitric acid it loses colour; nitrous acid is evolved, and on cooling, carbazotic acid is deposited in transparent yellow crystals. When these are neutralized by potash, and dissolved in hot water, the solution on cooling deposits crystals of carbazotate of potash. The acid can be precipitated from this salt by sulphuric acid. It is but little soluble in cold, but freely so in hot water, its solution leaving a bright yellow colour. It is highly poisonous, and gives a bright yellow colour to all the tissues of the body of a poisoned animal. In small doses it has recently been reported to possess specific virtues in the cure of intermittent fever. The carbazotic acid forms with potash a salt of difficult solubility, and is consequently used as a test to distinguish potash from soda. Many of the carbazotates on being heated, detonate like fulminating silver.

Red Dyes. Nearly all the substances used as red dyes are adjective colours. Of these the most remarkable are cochineal, lac, madder, logwood, and safflower.

Cochineal is an insect (the *Coccus Coccinelifer*) common in South America, and found occasionally in the Indian jungles. It feeds exclusively on the *cactus*, from which it is commonly supposed to derive its colour. The red dye which it contains is soluble in water, but being an adjective one, the colour can only be fixed on cloth by means of alumina, oxide of tin, or similar bases. Its true colour is very deep red, but if tartaric acid or cream of tartar be added, it gives a rich scarlet dye. *Carmine* is a lake made by precipitating an alkaline solution of cochineal by the muriate of tin.

SAFFLOWER is the dried flower of the *Carthamus tinctorius*, and is grown extensively in India. The well-known *rouge* is prepared from this dye.

LAC-DYE occurs in solid cakes, which are prepared by a great variety of processes from the aqueous solution of the colouring matter of the lac insect, procured during the washing of the resin. This colouring matter is very soluble in water and in alkalies, but insoluble in acids. With the vegetable and animal acids it forms insoluble compounds, in which the colour is unimpaired. By the mineral acids it is also precipitated, but its colour is usually injured by the process. As evaporation of the watery solution is, under ordinary circumstances, a very expensive and uncertain process, the manufacturers usually employ some weak acid, such as sour milk, or the fermented toddy, to throw down the colouring matter, which is subsequently pressed into cakes. This substance is soluble in alkaline solutions, and with muriate of tin and cream of tartar gives a splendid scarlet dye.

When the colouring matter has been removed by washing, the resin is placed in long bags, and roasted before a common fire; the resin undergoes slow liquefaction, is forced through the tissue by twisting, and is scraped off and spread on plantain stalks and leaves, from which on cooling it is detached in scales called *shell-lac*. The remains of the insect, with vegetable and animal matter, are left within the bag in a black spongy mass. Nothing can be more wasteful or clumsy than this process.

The colour of the product varies from deep red to light yellow. It is frequently mixed with a considerable percentage of dammer, and some specimens contain traces of orpiment, (yellow sulphuret of arsenic,) evidently added to give the orange tint so esteemed in the market.

Five hundred grains of shell-lac, according to the analysis of Mr. Hatchett, contain red extract 2½, resin 454½, vegetable gluten 14, wax 20.

Shell-lac is used in great quantities in the manufacture of sealing-wax and varnishes. It is soluble in alcohol, insoluble in water, and fuses only at a much higher temperature than other resinous bodies, to which property it owes its chief value in the arts.

MADDER, (*manjit,*) is cultivated to a great extent in India, and owes its colouring properties to a crystalline principle, termed *Alizarine.* Ten parts of madder are digested in four of ether, the solution evaporated to the consistence of a syrup, and then allowed to dry spontaneously. The residue is reduced to powder, and sublimed by a gentle heat from a watch-glass covered with a cone of paper. Yellowish red soft crystals collect in the cone. They are insoluble in cold, and scarcely soluble in hot water, but dissolve in 210 times their weight of alcohol and 160 of ether.

Madder enters into the composition of a multitude of dyes, and is one of the chief ingredients of the celebrated Turkey-red. The bones of young animals fed on madder become perfectly red in a few weeks.

Yellow Dyes. Quercitron, woad, turmeric, wild hickory, fustic, and saffron, are the most remarkable of these dyes, all of them being adjective colours. Very lately a dye has been extracted by Dr. Burt of Múrshedábád, from the leaves of the teak tree, and which is said to be a substantive colour.

The colouring principle of saffron is called *polychroite,* and is prepared by making an extract of saffron in water. It has a bright yellow colour, changed to blue and lilac by sulphuric acid, and receives a green tint from nitric acid.

Black Dyes consist essentially of the same materials as writing-ink,—namely, tannic and gallic acid, and the oxide of iron. By the addition of logwood, or sapan, and a salt of copper, the black shews a tint of blue.

Besides the organic colouring matters, a vast number of fine dyes are formed by mineral and metallic colours. A solution of orpiment in ammonia communicates a bright yellow. Prussiate of potash gives a blue dye with persalts of iron, and a brown dye with the salts of copper. The chromate of potash with salts of lead gives a yellow colour,

It would be impossible to give in this Manual even an outline of the various operations in the art of dyeing. The preceding sketch suffices to explain the broad principles of the art. For manufacturing details the reader is referred to Dr. Bancroft's work on Permanent Colours, to the American edition of "Gray's Operative Chemist," and to *Ure's* admirable *Dictionary of Arts, Manufactures, and Mines.*

VEGETABLE ALBUMEN, GLUTEN, YEAST.

Vegetable Albumen occurs in many seeds and vegetable juices. It is soluble in cold, coagulated by hot water; is precipitated by acids, prussiate of potash, and corrosive sublimate. It contains nitrogen, and readily putrefies, emitting a very offensive smell.

Gluten. In the process for separating starch from flour by washing, a tough elastic white mass remains in the muslin bag. This is vegetable gluten. It is insoluble in water and ether, but is readily dissolved by hot alcohol, acetic acid, and by alkaline solutions. It putrefies quickly while moist, but if dried by a gentle heat it may be preserved without change. This principle contains nitrogen, and is highly nutritious; it exists in most kinds of grain and pease, but is most abundant in wheat, the flour of which contains from 20 to 25 per cent. of this principle.

When moistened gluten is rubbed with powdered guaiacum, a fine blue colour appears.

Yeast or Barm. This substance, as Dr. Turner states, is always generated during the fermentation of vegetable juices containing sugar. It is a viscid frothy compound, the nature and composition of which have not been accurately ascertained. It is insoluble in water and alcohol, and putrefies quickly, owing to its containing nitrogen. It may be dried, however, by gentle heat, and in this state, like gluten, it can be preserved for any period. Its most singular property is its power of exciting fermentation, of which we shall meet examples under that head.

ASPARAGIN, BASSORINE, SALICINE, ETC.

Asparagin exists in the asparagus, marshmallow, liquorice, &c. It crystallizes in prisms; is colourless, and devoid of odour. It is dissolved in 58 parts of cold water, and insoluble in alcohol and ether. It contains nitrogen, and yields ammonia when decomposed by heat.

Bassorine is the chief ingredient of gum tragacanth and salep. It forms a bulky jelly with cold water, but is insoluble in that fluid, or in alcohol and ether.

Caffein is prepared from raw coffee by adding subacetate of lead to its solution in hot water. This precipitates the extractive and colouring matter. By transmitting a current of sulphuretted hydrogen gas, any lead in solution is thrown down, and a clear liquid containing the caffein remains and affords it in crystals by evaporation. It is a white volatile substance, very soluble in hot water and alcohol, and deposited from these solutions in silky crystals. Though it contains 2 eq. of nitrogen, it does not undergo putrefaction under any circumstances.

Cathartin is the active principle of senna, and is prepared by a process like that just described.

Fungin is the fleshy principle of mushrooms; is highly nutritious, and in composition resembles animal matter.

Lupulin is contained in the flowers of the hop, and is supposed to be the cause of the narcotic properties of that plant.

Piperin is a white crystalline substance, extracted from black-pepper, and lately recommended as a remedy for intermittent fevers. It is prepared by digesting for two days sixteen ounces of black-pepper in twice its weight of water, repeating this several times, and then acting on the insoluble parts with twenty-four ounces of strong alcohol for three days. The solution is filtered and evaporated to the consistence of a syrup, which on cooling deposits the piperin in prismatic crystals of a yellow colour, insoluble in water, but freely dissolved by alcohol and acetic acid.

Plumbagin is a crystalline principle, found in the *Plumbago Europæa,* and which is remarkable for yielding a red colour with solutions of alkalies, acetate of lead, and permuriate of iron. Its taste is sweet and acrid, and it is, very probably, possessed of medicinal virtues. It may also be prepared from the *P. rosea* and *zcylanica (làl chitra,)* plants, abundant in Bengál.

Chlorophyle is the name given by several writers to the colouring matter of leaves.

Salicine is a very important vegetable principle, found in the bark of the willow, aspen, and poplar. It is a certain specific for intermittent fever. M. Leroux received the Monthyon prize of 5000 francs for his discovery of this substance. It is prepared by making a decoction of the bark in water, adding subacetate of lead as long as a precipitate falls; filtering, boiling with chalk to throw down any lead remaining in solution, and then evaporating nearly to dryness. The salicine is deposited in crystals, which must be purified by digestion with animal charcoal and solution in alcohol.

Pure salicine is white, crystallizes in fine prisms, and is very bitter. It is freely dissolved by boiling water and alcohol, insoluble in ether, and decomposed and changed to a purple colour by strong sulphuric acid. It has neither acid nor alkaline properties, and is composed of 2 eq. carbon, 2 eq. hydrogen, and 1 eq. of oxygen.

Populin exists in the *leaves* of the aspen, and is prepared by the same process as salicine. It occurs in white silky crystals, but is not possessed of medicinal properties.

Sinapisin is extracted from mustard seed by adding subacetate of lead to its decoction in water, filtering, transmitting sulphuretted hydrogen, and concentrating the filtered solution. The sinapisin is deposited in white crystals, of bitter taste, destitute of odour, soluble in water and alcohol, decomposed by muriatic acid with the evolution of prussic acid vapours, and converted by sulphuric acid into the sulpho-cyanic acid. Evaporated with potash, the sulpho-cyanuret of potassium is formed.

Mudarine has been obtained by Dr. Duncan from the root of the *mádár*. It is not crystallizable, is more soluble in cold than hot water, and is possessed of emetic properties.

SECTION VII.

FERMENTATION.

To the spontaneous changes by which many vegetable substances undergo alteration in composition, the term *fermentation* is applied. This action is of several kinds, each being distinguished by the specific character of the new products it originates.

Sometimes the change alluded to tends to the formation of sugar; in other instances alcohol, in many acetic acid is the characteristic product. Lastly, the most remarkable and universal decomposition is that in which the whole arrangement of the compound is subverted, and decay and putrefaction take place.

The first of these varieties is termed

THE SACCHARINE FERMENTATION.

Starch and the vegetable acids are the only substances known to undergo this change. When starch or amidine is kept for some time in a moist state, about half its weight of sugar is formed. This new arrangement of the elements of starch is not dependent on, but is much promoted by, the presence of the air.

In the ripening of fruits, by a similar process the acids these contain in the green state gradually disappear, and sugar is formed. In the living plant it is obvious that this change might be accounted for by supposing that these acids are absorbed while sugar is secreted, but the researches of Couverchel have shewn, that exactly the same conversion of proximate principles occurs even when the fruit has been removed from the tree.

ARTIFICIAL GERMINATION—MALTING.

The chemical phenomena of natural germination and vegetation have already been described. Artificial germination is frequently effected by exposing grain to a warm and moist atmosphere. This process, which is called *malting*, constitutes the first step in the operations of the brewer and distiller of several kinds of spirits. The grain is steeped in water for two days, then removed to a frame, where it is laid in heaps, 30 inches deep, for about thirty hours. The grain becomes warm, but as its temperature is still unequal, it is next spread in layers a few inches thick on spacious shaded floors. It remains in this state for twelve or fourteen days, by which time the radicles have protruded and sugar is abundantly formed. At this stage the germination must be stopped, which is accomplished by strewing the *malt*, as it is now called, in kilns, wherein it is gradually heated from 100° to 160°.

According to Prout's analysis, there are—

	In 100 *parts of Barley.*	*In* 100 *parts of Malt.*
Resin, ...	1	1
Gum,.....................	4	15
Sugar, ...	5	15
Gluten, ...	3	1
Starch, ...	32	56
Hordein, or modified starch,	35	12

The chemical changes are, in fact, the same as in natural germination, and have already been described. During the process of malting a loss of weight is experienced in the grain, varying from one-fifth to one-third of the entire.

VINOUS FERMENTATION.

Whenever sugar, water, and yeast, are mixed together and exposed in close vessels for some time to a constant heat, ranging between 60° and 100°, carbonic acid is rapidly disengaged; the solution becomes turbid and warm; the sugar gradually disappears, and alcohol is found in its stead. The yeast meanwhile is altogether unaltered. The weight of the sugar which is decomposed is exactly that of the alcohol, and carbonic acid produced. Thus, if 6 eq. of sugar undergo fermentation, the products are thus represented:—

	Sugar.	*Alcohol.*	*Carbonic Acid.*
Carbon, ...	36.72. 6 eq.	24.48. 4 eq.	12.24. 2 eq.
Oxygen, ...	48 — 6 eq.	16 — 2 eq.	32 — 4 eq.
Hydrogen, ...	6 — 6 eq.	6 — 6 eq.	
	90.72	46.48. 1 eq.	44.24. 2 eq.

In the practical application of these facts in the art of the distillation of spirits, starch in various forms is often substituted for sugar, into which it is converted by the first kind of fermentation, before any alcohol can be formed. This change occurs with such facility, that during the baking of bread a considerable portion of the starch is converted into sugar, and this again into alcohol and carbonic acid. A very strong spirit may be obtained by leading tubes from close ovens in which bread is baked, and condensing the volatile products in a cool receiver.

In the manufacture of wines, the natural juices of the plant or fruit act instead of yeast, in exciting the fermentation; but in this case exposure to the air is essential.

ACETOUS FERMENTATION.

When diluted alcohol is mixed with yeast and exposed to the warm air, carbonic acid is disengaged, and the alcohol is changed into acetic acid. This kind of fermentation does not occur at low temperatures, but is very rapid when the thermometer ranges between 80° and 100°. Alcohol, water, and yeast are the essential ingredients, but the action proceeds, whatever other organic principles may be present; for instance, in wines, beers, and all other liquids which have undergone the vinous fermentation.

There is still so much doubt and uncertainty as to the exact nature of the ultimate changes of arrangement which occur in this decomposition, that it would be of little utility to consider the subject more mintuely here.

PUTREFACTIVE FERMENTATION.

Those substances alone undergo putrefaction, the oxygen and hydrogen of which are in the ratio to form water, and especially such as contain nitrogen. Alcohol, the oils and resins, and the acids with excess of oxygen, do not decay; and of azotized bodies there are some, such as caffein and many vegetable alkalies, which still do not putrefy.

Moisture, air, and the range of heat between 60° and 100° are the circumstances most favorable to vegetable decomposition of this kind. If the heat be so great as to expel the moisture, or if the thermometer descend below the freezing point of water, the putrefaction, even of animal substances, is totally arrested. Thus, in the sands of Arabia the bodies of travellers overwhelmed by the Simoom, dry up totally, and remain otherwise unchanged. In cold countries, on the other hand, the preservation is effected under opposite circumstances. Frozen meats and vegetables are sent from the interior of Russia to St. Petersburgh. The produce of the country markets of Holland is transported while congealed in perfect freshness to the capital. Nay, so perfect is this conservative power that the carcass of an elephant was some years since found in an iceberg in Siberia, in which it had been lodged for many hundred winters. Modern travellers may frequently contemplate a similar phenomenon in another form in the sepulchres of the monastery of St. Bernard, in Switzerland. In these alpine regions the bodies of persons who perish in the snows undergo no putrefaction, and have often been recognized in perfect form and feature after the lapse of several years.

The putrefaction of vegetables gives rise to the formation of hydrogen and carbonic acid, ammonia (if nitrogen be present), light carburetted hydrogen and carbonic acid gases. Acetic acid, oil, and water are also generated; a dark, solid, pulverulent matter remains, which forms the basis of the mould of soils.

The miasmata, which generate fevers and many other epidemic diseases, are formed during this decomposition, but they have never been obtained in a separate state, and all speculations on their origin and nature are as yet merely hypothetical.

PART THE FOURTH.

ANIMAL CHEMISTRY.

Animal matters are resolvable by analysis into several ultimate constituents, all of which contain carbon, hydrogen, and oxygen: some, nitrogen, others, sulphur and phosphorus. The majority leave on incineration traces of earthy and saline matter and of the oxide of iron.

The *proximate* animal principles are those which themselves contain the *ultimate* ingredients above noticed, but still exhibit distinct and characteristic properties.

Animal compounds are arranged in three sections. The first contains those which are neither acid nor oily; the second embraces the animal acids; and the third treats of the animal oils and fats.

SECTION I.

FIBRINE, ALBUMEN, GELATINE, ETC.

Fibrine is the basis of muscular tissue, and is contained in the blood of most animals. It is obtained pure by enclosing a clot of blood in muslin, and washing it under water which removes all the other principles of the blood, and leaves the fibrine in the form of a white elastic, ductile thready mass. When dried at a gentle heat, this becomes brittle and transparent like gum.

Fibrine is insoluble in water, and is changed by strong alcohol into a fatty substance soluble in alcohol and ether, and insoluble in water. In strong acetic acid, fibrine increases in size, and subsequently dissolves on the addition of hot water. Warm nitric acid (sp. gr. 1.25), dissolves this principle, forming a yellow solution, disengaging pure nitrogen in large quantities, and depositing a pale yellow substance formerly called the *yellow acid.* The nitric acid is not the source of the nitrogen, for it may be recovered from the solution unchanged, after a large quantity of the gas has been evolved.

Dilute muriatic acid hardens, the strong acid corrodes fibrine. Strong sulphuric acid dissolves it, the colour of the solution being unchanged, and no sulphurous acid being disengaged. By saturating the solution with chalk, the filtered solution yields a white animal matter called *leucine.* Fibrine is dissolved also by potash, and is precipitated by neutralizing the solution. The precipitate is not soluble in acetic acid.

ALBUMEN.

This principle exists in large quantities dissolved in the serum of the blood, in the white of eggs, and in the fluids secreted from inflamed serous membranes. It is also present in the solid form in various structures of the body, such as the skin, glands, vessels, &c.

When the serum of the blood, or white of eggs, is evaporated at a gentle heat (below 120°), a transparent, colourless mass is obtained, which is soluble in water, insoluble in alcohol and the acids. The watery solution is coagulated by a temperature of 212°, while serum, or the white of eggs, becomes solid at 160°. This character distinguishes albumen from all other liquid animal principles.

The sulphuric, muriatic, nitric, and tannic acids coagulate albumen; and of the three isomeric varieties of the phosphoric acid, the metaphosphoric alone produces the same effect. Strong sulphuric acid dissolves albumen, and by the application of a very gentle heat the solution assumes a fine red colour.

Corrosive sublimate occasions in albuminous solutions, even when very much diluted, a precipitate usually regarded as a compound of solid albumen and calomel, but which has recently been stated by Rose to consist of albumen and the oxide of mercury. Several other metallic compounds, especially the acetate of lead and sulphate of copper, produce a similar effect. In albuminous solutions, previously slightly acidulated with acetic acid, the ferro-cyanuret of potassium occasions a copious precipitate. But the most delicate of all the tests of albumen is the effect of a galvanic current which causes the coagulation of this principle round the positive or anode wire.

In medical practice these tests are often had recourse to, to ascertain the condition of the urine in various affections of the kidnies and other organs.

Coagulated albumen is insoluble in water, is dissolved by alkalies, precipitated by acids, and is with great difficulty distinguished from fibrine.

GELATINE.

To this principle allusion has been made at page 319. It is present in very large proportions in various parts of the bodies of animals, especially in the skin, cartilages, tendons, membranes and bones. It is very soluble in boiling water, and as the solution cools, it forms a bulky jelly. On evaporating this jelly to dryness by a gentle heat, the gelatine is again obtained.

Glue is a coarse variety of gelatine, prepared by boiling cuttings of the skins, ears, and hoofs of animals in water, and evaporating to dryness. *Isinglass* is the purest kind of gelatine, and is prepared from the sounds of the sturgeon.* An excellent gelatine, now much used as an article of diet, is made from the bones of various animals. These consist chiefly of

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* The Suleah fish of the Ganges, (*Polynemus Sele,*) also yields this substance.

phosphate of lime, and this principle. By acting on the bones with muriatic acid, the earthy matters are dissolved, and a flexible mass of gelatine retaining the form of the bone is procured. On washing this in cold water and then boiling it, a rich and nutritious solution is obtained. The use of muriatic acid may be dispensed with by heating the bones with water in the apparatus called *Papin's digester*, in which the temperature of the contents of the vessel can be raised to a degree far above that of boiling water. The construction of this vessel will be explained in another volume. The highly heated water penetrates the texture of the bone, and dissolves out its gelatine. Soup thus prepared has been of late much used in the French hospitals, and on a recent expedition to Algiers, the French army were supplied with biscuits composed of flour and gelatine of this description.

Gelatine is insoluble in alcohol, but dissolved by most of the acids and by the alkalies. It is not precipitated by corrosive sublimate or acetate of lead, but the tannic acid will occasion a precipitate of gelatine from water containing only one part in 5000 of that principle. It is to be borne in mind, however, that tannic acid precipitates albumen also.

UREA.

This principle has been described already. It is useful to compare here its composition with that of the three other substances described in this section.

	Carbon.	*Hydrog.*	*Nitrogen.*	*Oxygen.*
Fibrine, ...	53	7	19	19
Albumen, ...	50	7	15	28
Gelatine, ...	47	7	16	27
Urea, ...	19	6	46	26

SECTION II.

THE ANIMAL ACIDS.

The most important of these compounds have been described in other parts of this Manual.

The uric and purpuric acids are described at page 152; the formic acid at page 150; the stearic, oleic, and margaric acids at page 199.

An acid, called the Rosacic, is frequently mentioned in works on practical medicine, as existing in the red matter (lateritious sediment), deposited from the urine in some stages of fever. The nature of this substance is however uncertain, and the probability seems to be that it is uric acid combined with ammonia and animal matter.

Hippuric Acid exists in the urine of the horse, from which it is deposited on adding an excess of muriatic acid. The deposit is purified by boiling with lime diffused through water, and adding small quantities of chloride of lime until all urinous odour ceases. The mixture is then treated with animal charcoal, and on mixing the hot filtered solution with muriatic acid, the hippuric acid is deposited in crystals two or three inches long, and very white. In many of its properties it resembles the benzoic acid, but differs from it in containing nitrogen.

Allantoic Acid. This is only of interest to the medical student. It is the acid principle of the liquor found in the allantois, and is now proved to proceed from the urine of the fœtal calf. It is obtained, in small white crystals, by evaporating the liquor contained in the allantois. It forms several salts, but is destitute of any important characters.

SECTION III.

OLEAGINOUS SUBSTANCES.

Of these the most important have been already described. For an account of stearine, margarine, oleine, and glycerine, with their corresponding acids, the reader is referred to pages 197—199.

SPERMACETI, ADIPOCIRE, CHOLESTERINE, AND AMBERGRIS.

Spermaceti oil is obtained from a fatty substance contained in a bony cavity in the head of the spermaceti whale. On pressing this substance in bags the oil exudes; the residue is melted, strained, and boiled with potash, and constitutes the solid spermaceti. It is of white colour and talcy lustre: brittle, soft, and slightly unctuous; insoluble in water, but dissolved by thirteen times its weight of hot alcohol, from which, on cooling, it is deposited in scales like sulphate of quinine. The spermaceti thus purified is called *cetine.*

Adipocire is a substance very remarkable for the mode of its formation and its composition. When fat and muscular flesh, or fibrine of any kind, are exposed for some time to the action of water, or are kept in moist earth, the fibrine disappears, and in its stead this substance is deposited. It is white, greasy, and fusible; yields ammonia on distillation, or by the addition of potash, and on analysis is found to consist of the stearic and margaric acids, furnished by the fat, and ammonia generated by incipient decomposition of the fibrine. In certain cemeteries, the soil of which contains chalk or gypsum, this ammoniacal soap is again changed by double decomposition into stearates and margarates of lime, while the ammonia is totally removed.

The time required to accomplish this change varies according to the circumstances in which the body is placed. MM. Orfila and Le Sueur have established that it does not occur *completely* in less than three years, when bodies are buried in moderately dry earth. In wet soil, and especially under water, the transformation is much more rapid. The following anecdote gives an interesting example of the occasional importance of these facts in medico-legal inquiries:

"At the Lent assizes held at Warwick, in the year 1805, the following cause came before the court. A gentleman who was insolvent, left his own house, with the intention (as was presumed from his recent conduct and conversation) of destroying himself. Five weeks and four days after that period his body was found floating down a river. The face was disfigured by putrefaction, and the hair separated from the scalp by the slightest pull; but the other parts of the body were firm and white, without any putrefactive appearance. The clothes were unaltered, but the linen was exceedingly rotten. On examining the body, it was found that several parts of it were converted into adipocire.

" A commission of bankruptcy having been taken out against the deceased a few days after he left home, it became an important question to the interest of his family, to ascertain whether or not he was living at that period. From the changes which the body had sustained, it was presumed that he had drowned himself on the day he left home; and, to corroborate this presumption, the evidence of Dr. Gibbes, of Bath, was requested, who, from his experiments on this subject, was better acquainted with it than any other person. He stated, on the trial, that he had procured a small quantity of this fatty substance by immersing the muscular parts of animals in water for a month, and that it requires five or six weeks to make it in any large quantity. Upon this evidence, the jury were of opinion that the deceased was not alive at the time the commission was taken out, and the bankruptcy was accordingly superseded."—*(Beck's Medical Jurisprudence.)*

Cholesterine is a crystalline matter, chiefly found in the gall-stones of the human subject. It is white, brittle, and lustrous; fuses at 278°, and is not changed into soap by potash. It dissolves copiously in hot alcohol, from which it crystallizes on cooling. It decomposes nitric acid, and forms a yellow acid insoluble in water, called the *Cholesteric.*

Cholesterine is found also in the bile of man and of several of the lower animals, and very frequently in abscesses, tumours, and collections of fluids in various parts of the body.

Ambergris, (*Ambar,* انبر Hind.) is found floating on the sea near the coasts of many tropical countries. Its origin is rather uncertain. Swediaur states, that it is found in the intestines of the spermaceti whale. The chief constituent strongly resembles cholesterine, and has by Pelletier and Caventon been named *ambreine.* With nitric acid it yields the ambreic acid.

SECTION IV.

COMPOSITION OF THE HUMAN BLOOD.

A sufficiently detailed notice of this subject is given in the first part at page 74, while the several constituents of this complex fluid are described under their respective heads. For the use of the medical student, I append the results of Lecanu's analysis, for which he obtained the gold medal of the French Academy.

STANDARD ANALYSIS OF THE BLOOD.

By M. L. R. Lecanu.

Journal de Pharmacie, No. IX, September 1831, p. 502.

Water,	780.145	785.590
Fibrine,	2.100	3.565
Albumen,	65.090	69.415
Fatty matter:		
a. crystalline,	2.430	4.300
b. oily,	1.310	2.270
Colouring matter,	133.00	119.626
Extractive, *soluble in alcohol* and *water*,	1.790	1.920
Albumenate of soda,	1.265	2.010
Muriate of soda,	8.370	7.304
Muriate of potassa,		
Carbonate,		
Phosphate, Alkaline,		
Sulphate,		
Carbonate of lime,	2.100	1.414
Carbonate of magnesia,		
Phosphate of lime,		
Phosphate of magnesia,		
Phosphate of iron,		
Loss,	2.400	2.586
Total,	1000.000	1000.000

The relative proportion of these ingredients varies slightly according to the sex and age of the individual. Thus, in ten men and ten women, Lecanu found

	Female.	*Male.*
Water,	804	789
Albumen,	69	67
Saline and extractive matter,	9	10
Red globules	115	132

But in several diseases, especially in scurvy and the malignant cholera, the alteration is very remarkable. In the latter disease my experiments have shewn the ingredients in the *serum* of the blood to be in the following proportion:

COMPARATIVE ANALYSIS OF STANDARD AND CHOLERA SERUM.

Ingredients.	Standard of Lecanu.	Serum from cholera patient.	Remarks.
Water,	906.00	854.00	
Albumen,	78.00	133.00	
Urea,	0. 0	0.40	
Organic matter:			
Soluble in alcohol and water,	1.69	*4.80	* The number in 2nd column embraces both the *organic matter* and *albumenate of soda.*
Albumen combined with soda,	2.10		
Fatty matter:			
a. crystalline,	1.20	†1.40	† 2nd column includes both the *oily* and *crystalline* principles.
b. oily,	1. 0		
Muriate of soda, Muriate of potassa,	6. 0	4.00	‡The 0 in 2nd column refers to the carbonate of soda alone.
Sub-carb. of potassa Phosphate of ditto, Sulphate of potassa,	2.10	‡0.00	
Carbonate of lime,		0.00	§ The 2nd column here embraces
Carb. of magnesia, Phosphate of lime, Phos. of magnesia, Phosphate of iron,	0.91	§1.60	*Phosphates of soda,* *Sulphates of soda,* Phosphates of lime, Phosphates of magnesia and iron, } 1.60
Loss,	1.00	0.80	
Total,	1000.00	1000.00	

The tabular view thus afforded of the results in this analysis, is interesting in several points of consideration. It shews, in the first place, the absence of a large proportion of water; secondly, the corresponding preponderance of albumen; thirdly, the presence of urea; fourth, the absence of the alkaline carbonate; fifth, a great *deficiency* of saline materials.

On these data I felt warranted in recommending, that in desperate cases of cholera, whenever all other means of cure were obviously hopeless, that the water and saline matter deficient in the blood should be restored to it artificially by injecting these substances through the veins. [See my Report on the Chemical Pathology of Cholera, published by the London Central Board of Health, p. 54, January, 1832.] The operation was accordingly performed by Drs. Lewins and Latta, of Leeds, in the following month, and with perfect success, and Dr. Girdwood, of London, rescued by its means five utterly abandoned cases. In many instances it was unsuccessful, as might be reasonably expected, for death had already secured the sufferers. In some cases the measure failed through the inexperience of the operators, and the introduction of air into the veins. In no one instance has it ever accelerated the progress of the disease, or produced any symptoms indicative of its having itself occasioned harm. Seventeen cases are now recorded of its success; and as its adoption is only recommended where all other remedies are given over in despair, I regard the operation as one which should be always resorted to before we abandon our patients.

THE COLOURING MATTER OF THE BLOOD, OR HEMATOSINE, is obtained nearly pure by cutting the clot into small pieces, and washing these in cold distilled water. The filtered solution is evaporated to dryness in shallow vessels, at a temperature of 100° Faht. When dried it is black, but is red if reduced to powder; it is soluble in cold water, forming a red liquid coagulable by heat, and precipitated by alcohol and acids. Though strongly resembling liquid albumen in several properties, it still differs from that principle in not being precipitated by acetate of lead, and by the precipitate which it yields to muriatic acid being dissolved by strong alcohol.

Hematosine consists of carbon, oxygen, hydrogen, and nitrogen, nearly in the same proportions as in fibrine and albumen; but besides these it contains iron. By passing a current of chlorine gas through a solution of hematosine, the colour disappears, some coagulated albumen is thrown down, and a transparent solution is formed, in which iron may be detected by the tincture of galls, meconic acid, or ferro-cyanuret of potassium.

It was long supposed that the blood owes its colour to the iron thus shewn to be present, but this opinion is no longer maintained.

A solution of hematosine in water has been used in dyeing. It gives a fine and permanent red colour to clothes previously soaked in corrosive sublimate, or per-nitrate of mercury.

It sometimes becomes necessary in criminal inquiries, to analyse supposed blood stains on clothes. The stained cloth should be washed with a little distilled water, and the solution boiled, when the albumen will coagulate. If the whole be now evaporated to dryness and incinerated on platinum leaf, the ash will give indications of iron with the usual re-agents. These tests will supply evidence of the nature of a stain not larger than a four-anna piece.

The *coagulation* of the blood is not susceptible of explanation according to the present state of chemical or physiological science.

SECTION V.

THE SALIVA, PANCREATIC AND GASTRIC JUICES.—DIGESTION OF FOOD.

Saliva consists of water, mucus, traces of albumen, a substance soluble in water, but insoluble in alcohol, and various saline matters, especially the muriate, sulphate, phosphate, acetate, and sulpho-cyanate of potash, owing to the last of which, saliva receives a red colour from the persalts of iron. The solid contents of saliva are not more than 7 in 1000 of water.

Salivary concretions are generally composed of carbonate of lime, phosphate of lime, and animal matter; the first ingredient usually constituting nine-tenths of the entire.

The Pancreatic Juice differs chiefly from saliva in the absence of the sulpho-cyanate of potassa. The uses of this fluid are unknown.

The Gastric Juice is the chief agent in effecting the digestion of our food. It is a transparent fluid acid, if obtained during digestion, but neutral while the stomach contains no food or stimulating substances. The acid has been fully proved to be the muriatic, with traces of the acetic. It coagulates milk, prevents putrefaction, and dissolves a vast number of vegetable, animal, and mineral substances. When the food arrives in the stomach, it is thus dissolved, and converted into a pulpy matter called *chyme*. When this passes into the small intestines diluted by the accession of drink, and the saliva and pancreatic juices, it is acted on by the absorbent vessels or lacteals, and its finer portions carried into the circulation chiefly through the thoracic duct. The fluid collected from this tube is termed *chyle;* it is white, opaque, and milk-like, and coagulates soon after being drawn. The clot is of a slightly pink colour, and seems to consist of modified *fibrine*. The serum of the chyle contains *albumen*. In other respects, the composition of this fluid strongly resembles that of the serum of the blood.

The gastric juice is sometimes so corrosive, that it destroys the coats of the stomach even in living animals, and in dead bodies this occurrence very frequently takes place.

The solvent power of this fluid is destroyed by neutralization with alkaline substances, such as soda or magnesia. Dr. Prout believes that the neutral salts contained in the blood undergo galvanic decomposition during digestion; that their acid is poured into the stomach, and acts upon the food, while the alkali returns into the circulation, where it is found in the free state in the serum of the blood. Whether the galvanic agent be the cause or not, the facts are, at all events, exactly as Dr. Prout describes them.

THE BILE.

This is a yellowish fluid, of variable consistence, rather heavier than water, of alkaline re-action, and composed of a great number of ingredients. In man, according to Thenard, Tiedemann and Gmelin, Chevallier and Chevreul, it contains water, salts, colouring matter, albumen, resin, cholesterine, and a principle named picromel.

I have lately found that the bile also contains a considerable proportion of *urea*, the principle so long deemed to be characteristic of the urine alone. My experiments on this subject have not yet been published. But they will give rise to some important physiological speculations.

Picromel is obtained by a very complicated and uncertain process. The bile is precipitated by acids, and the deposit contains some picromel, resin, colouring matter, mucus, and margaric acid, with traces of the acid employed. Acetate of lead is added to the solution; another precipitate of the acids and of the saline matters of the bile with the oxide of lead is formed. The *sub*-acetate of lead is lastly used, and this precipitates all the picromel with resin and oxide of lead. This *last* precipitate is suspended in water and decomposed by sulphuretted hydrogen, which separates the lead, precipitates the resin, while the picromel is dissolved, and may be purified by evaporation and solution in alcohol.

Pure picromel is crystalline, soluble in water and alcohol, and insoluble in ether. Its taste is very sweet, and it contains nitrogen. When mixed with resin the taste is bitter, followed by sweetness, and hence the picromel derives its name.

No quantitative analysis has yet been published of the bile of man. In the ox 800 parts, according to Thenard, contain water 700, resin 15, picromel 69, colouring matter 4, the residue being salts of various kinds. Another analysis has been made of the same fluid by Tiedemann and Gmelin, who have shewn it to contain cholesterine, asparagin, and other substances of less note.

Biliary Calculi, or gall-stones, are in man formed of the colouring matter of the bile and cholesterine. These principles may be separated by hot alcohol, which dissolves the cholesterine and leaves the colouring matter, or by potash, in which the latter is exclusively dissolved.

The colouring principle of bile is of a fine yellow colour, and is much used by painters. It is turned to green by nitric or muriatic acid. The last acid is so delicate a test of bile, that it discovers it in the urine and blood in several states of disease, especially in jaundice.

SECTION VI.

MILK—EGGS.

Milk consists of three parts, the cream, curd, and whey, into which it separates by rest.

The *cream* is a dense yellowish fluid, of agreeable taste, and is composed of butter 4 parts, cheesy matter 3 parts, and whey 92 parts per cent. The butter may be separated by agitation as in churning, the whey becomes sour and the temperature of the mixture rises three or four degrees.

After the separation of the cream, milk coagulates spontaneously, and this may be hastened by the addition of any acid, or by the fluid called *rennet*, which is the infusion of the inner coat of a calf's stomach in water, and which acts on the milk by the acid it contains.

The coagulated matter, caseum or curd, is the basis of cheese. It is white, insipid, inodorous; insoluble in water, freely dissolved by alkalies and by acetic acid. If milk be coagulated by sulphuric acid, and the curd dissolved in the least possible quantity of carbonate of potash, on the cautious addition of alcohol, sulphate of potash, and some caseum are thrown down, and the filtered liquor contains pure caseum dissolved in water. When dried it resembles gum, is very adhesive, and when flavored with sugar and aromatic substances, may be used as an article of diet. It may be preserved for many months, and if mixed with small quantities of water, butter, and sugar, it makes a good substitute for milk on long voyages or journies.

A much better substitute can be prepared, however, by evaporating perfectly fresh milk to dryness, at the temperature of 100°. The process requires attention to prevent the temperature rising, which would curdle the milk, and the fluid must be in very shallow pans, in order to accelerate the evaporation. The heat should be applied by a water-bath. The milk thus treated dries perfectly, keeps for months, and retains its solubility in water. The flavour of the solution is exactly that of fresh milk. The powder makes excellent custards and puddings, and is a capital article of food, even of luxury, at sea. The process I now describe, I communicated to *Mr. Previté* of this city, who succeeded thereby in preparing what he calls his "*pulverized milk,*" which when *made as I describe,* I can confidently recommend; but I do not at all consider myself responsible for the goodness of the article, as its value altogether depends on the care bestowed on the several steps I have enumerated.

When curd is allowed to putrefy, some complicated products are obtained, which are separated by alcohol into two parts: that which is soluble is called the *caseate of ammonia* by many writers; the insoluble portion has been termed the *caseous oxide.* The existence of both these products has been denied on strong grounds, and the products of the putrefaction stated to be margarate of lime, margaric, and oleic acid, and animal mater.

Caseous matter yields on incineration about six per cent. of phosphate of lime, on which account it is recommended as food for very young animals, in whose bones the gelatinous matter is very abundant.

According to Berzelius, 1000 parts of milk contain water 928, caseum and butter 28, sugar of milk 35, the remainder being lactate of soda, and other saline and earthy substances. When the caseous matter and butter are abstracted, the remainder constitutes whey.

Eggs consist of two parts, the *white* and the *yelk*. The former is composed of water, albumen, and sulphur; the yelk contains albumen, oil, and a considerable proportion of phosphorus. The oil is separated by strong alcohol, which leaves the yelk colourless. The oil retains its fluidity in very low temperatures, and is hence used for lubricating watch machinery.

Egg-shells consist of about 95 per cent. of carbonate of lime. The remainder is composed of phosphate of lime and magnesia, with about two per cent. of animal matter.

SECTION VII.

LIQUIDS OF SEROUS AND MUCOUS SURFACES, AND PURULENT MATTER.

The contents of the absorbent vessels are called *lymph:* this is transparent and colourless; does not affect the colour of test-paper, and contains muriate of soda and traces of albumen dissolved in water.

The fluids secreted by healthy serous membranes, such as the pericardium, pleura, and peritoneum, resemble lymph very closely, and are composed of water 92 parts, albumen 5, mucus 2, and muriate of soda 2. The liquid which surrounds the human fœtus in the uterus is nearly of the same nature, but contains traces of caseous matter.

The *humours of the eye* are composed of 80 per cent. of water, with albumen, muriate of soda, &c.

The *crystalline lens* contains 36 per cent. of matter analogous to albumen. The *tears* consist of free soda, muriate and phosphate of soda, and some animal matter, probably mucus or albumen.

Mucus is a transparent, colourless, and viscid fluid, soluble in hot and cold water; is not precipitated by corrosive sublimate or tannin, does not gelatinise from its hot solutions, and is precipitated by subacetate of lead. Mucus secreted by the nose affords the best example of this fluid.

Pus is the yellow fluid secreted by ulcerated and inflamed surfaces. When a purulent sore is in a healthy state, (to use the language of surgeons,) the pus secreted is yellow, thick, and uniform; and when examined by the microscope, is found to consist of minute globules. Its specific gravity is 1.03. It is insoluble in water, thickened but not dissolved by alcohol. It is dissolved by the mineral acids, forms a thick fluid with the fixed alkalies, and is converted by ammonia into a jelly.

In practical medicine, (especially in the treatment of diseases of the lungs,) it frequently becomes very desirable to ascertain whether the liquid secreted by an inflamed organ is composed of pus or mucus. In the natural state these fluids can scarcely be mistaken for each other, but when inflammation of the secreting organ exists, mucus assumes all the physical appearances of pus. The following tests have been pointed out by Mr. Darwin.—1st. When the solution of these liquids in sulphuric acid is diluted, the pus subsides, the mucus remains suspended in the water.—2nd. Pus sinks, mucus floats on water.—3rd. Pus is precipitated from its solution in potash by water, while mucus is not decomposed in this manner. Grasmeyer states, that a solution of pus in carbonate of potash gelatinises in a few hours. I cannot, however, but express my conviction of the truth of the prevailing opinion, that these tests are all deceptive, and that when the secreted fluids so resemble each other, the state of the secreting surfaces must be so nearly the same as to render diagnosis impossible.

Sweat consists chiefly of water, and contains muriate of soda and free acetic acid.

URINE AND URINARY CONCRETIONS.

Urine is a transparent limpid fluid; sp. gr. 1.022; reddens litmus, and putrefies rapidly. According to the researches of Berzelius, it is composed of—

	In 1000 parts.
Water,	933=00
Urea,	30 10
Uric acid,	1 00
Lactates and animal matter,	17 14
Mucus,	0 32
Sulphate of potash,	3 71
——— of soda,	3 16
Phosphate of soda,	2 95
——— of ammonia,	1 64
Muriate of soda,	4 45
——— of ammonia,	1 50
Earthy matters,	1 00
Siliceous earth,	0 03

The acid re-action of urine is ascribed by Dr. Prout to the super-salts it contains, especially the super-phosphate of lime and super-urate of ammonia.

The composition of urine is remarkably modified in certain states of diseases. In *diabetes*, for instance, the kidnies secrete true *sugar*. 1000 parts of such urine have yielded on analysis 60 of sugar, and but 6 of urea. Urine of this kind undergoes the vinous fermentation, and on distillation, yields a very strong spirit.

The oxalic and nitric acids are sometimes generated in the urine. The former with lime forms a dangerous insoluble concretion in the bladder: the latter with uric acid produces the "lateritious sediment" of fevers, the purpurate of ammonia of Prout.

In many inflammatory conditions of the kidnies, albumen passes into the urine in such large quantity that this fluid coagulates when heated. In this state the urine is scanty, pale, and of low specific gravity, seldom higher than 1.013.

The urea is generally deficient. In such patients, urea is found in the blood in considerable quantities.

The uric acid is frequently secreted in undue quantity, or is separated from the urates in the bladder by the casual presence of some other acid. The acid thus deposited often accumulates, and gives rise to one of the most distressing forms of stone in the bladder. In this case alkaline remedies are of unquestionable utility, in as much as they combine with the uric acid, and render it soluble in water. It is worth recollection here, that the bi-tartrates and citrates of the alkalies, such as cream of tartar, when taken into the stomach, are converted into carbonate of potash, and act in this favourable manner on the calculus in question.

But it often happens, however, that from an opposite cause,—namely, deficiency of the natural acid, which keeps the phosphate of lime in solution, this earthy salt is deposited, and either constitutes the nucleus, or promotes the growth, of stone. Acid remedies are here indicated, and when judiciously administered they effect much good.

URINARY CALCULI.

These may be divided into six kinds :—1st, the uric acid calculus; 2nd, the phosphate of lime, or bone-earth; 3rd, the ammoniaco-magnesian phosphate; 4th, the fusible calculus, a mixture of the two preceding kinds; 5th, the mulberry calculus, composed of oxalate of lime; and, lastly, the cystic oxide.

1st. The *uric acid calculus* is hard, smooth, oval, fawn-coloured or brown, composed of concentric layers; insoluble in water and muriatic acid, soluble in alkalies; the alkaline solution is precipitated by acids. It is dissolved with effervescence by the nitric acid, the solution assuming a fine purple colour when heated nearly to dryness. Sometimes this calculus contains ammonia, which is disengaged from it by adding caustic potash.

2nd. The *phosphate of lime*, or *bone-earth calculus*, is of pale-brown colour, smooth and polished; of laminated texture, easily separated into shells; soluble in dilute nitric and muriatic acids, insoluble in potash; first blackened by heat, then becoming quite white, and unchanged by a red heat.

3rd. The *triple phosphate of ammonia and magnesia* usually occurs with the preceding deposit in the form of minute crystals. Such calculi are generally white, of comparatively loose texture, soluble in cold acetic acid; they emit ammonia on the addition of potash, and before the blow-pipe on charcoal melt into a white pearly globule.

4th. The *fusible calculus* is a mixture of both the preceding species. It is usually white, soft, and brittle.

5th. The *mulberry calculus*, so called from its resemblance to the fruit of that name, consists of oxalate of lime. It is of a dark colour, rugged tubercular surface, hard and compact. Before the blow-pipe its oxalic acid is destroyed, and pure lime is left. It is insoluble in alkalies, and when boiled with carbonate of potash, carbonate of lime is precipitated, and oxalate of potash remains in solution. It is not dissolved by acetic acid, by which it is distinguished from the ammoniaco-magnesian phosphate. It is insoluble in phosphoric acid, in which property it differs from the phosphate of lime.

6th. The *cystic oxide* is a very rare calculus. It is of crystalline structure, and compact; is consumed before the blow-pipe; is soluble in the mineral acids, alkalies, and alkaline carbonates; insoluble in water, alcohol, and acetic acids.

The *alternating* calculus means a stone in which two or more of the preceding kinds are deposited round each other. Some rare cases have been recorded, in which urinary concretions were composed of chalk, fibrine, an animal matter called the *Xanthic* oxide, and, lastly, *silica*.

Several attempts have been made to dissolve calculi by the injection of the appropriate solvents into the bladder, but the necessary solutions are too strong to be introduced without injury to that organ. Prevost and Dumas proposed the application of galvanic conductors for this purpose, but a battery of sufficient power to decompose such concretions would be altogether intolerable if brought into contact with so peculiarly sensitive and irritable an organ.

SECTION VIII.

BONES, HORN, TENDONS, LIGAMENTS, ETC.

Bones are composed of earthy and animal matter: the latter contains fat, gelatine, and cartilage, a substance identical with coagulated albumen. The gelatine may be removed by boiling water; the earthy matter is dissolved by muriatic acid.

When bones are heated to redness in close vessels, carbonate of ammonia, oil, and several gases are disengaged, and a mixture of charcoal and earthy matter called animal charcoal remains in the retort. Heated in an open fire all the animal matter and charcoal are consumed, and a white friable earth remains. Berzelius states, that 100 parts of dry bones contain 33 animal matter, 51 phosphate of lime, 11½ carbonate of lime, 2 fluate of lime, with 2½ of phosphate of magnesia, soda, and water. In some bones a small quantity of sulphate of lime and traces of alumina, silica, iron, and manganese have been detected.

Teeth contain no cartilage, and their enamel consists of 78 of phosphate, 6 of carbonate of lime, with gelatine. *Ivory* is of similar composition. The *shells* of eggs, lobsters, shrimps, prawns, oysters, muscles, &c. consist of carbonate of lime, and variable proportions of the phosphate with gelatine and cartilage. *Pearls* and *mother of pearl* are composed exclusively of animal matter and the carbonate of lime.

Horn, *nails*, *hoofs*, and *cuticle* contain only a trace of earth, and are chiefly composed of gelatine and coagulated albumen.

Tendons and the true skin contain nothing but gelatine. *Membranes* and *ligaments* along with gelatine, have coagulated albumen.

Hair, *wool*, and *feathers* contain a peculiar animal matter soluble in potash, together with oil, sulphur, iron, silica, manganese, carbonate, and phosphate of lime. The colour of the hair depends on that of its oil, and the effect of silver and lead in staining it is connected with the sulphur alone.

Quills, according to Mr. Hatchett's analysis, are formed of coagulated albumen.

Ozmazome is a peculiar extractive matter found in many of the solids of animals. To this principle is due the peculiar flavour of meat and soups. It is soluble in water and alcohol, and does not gelatinise on cooling.

The substance of the *brain*, *nerves*, and *spinal chord* consists of water, albumen, fatty matter, ozmazome, phosphorus, sulphur, and saline matter. M. Couerbe has also detected cholesterine in the brain. The quantity of phosphorus is usually about 1 or 1½ per cent., and is said to be most abundant, as high even as 4 per cent. in the brains of idiots and maniacs. The fatty matter of the brain yields phosphoric acid when deflagrated with nitrate of potash.

APPENDIX.

APPENDIX.

PART I.

GALVANIC ELECTRICITY.*

The earliest circumstance on record connected with this branch of science appears to be an observation by Sulzer in his *Theorie de plaisir*, that pieces of zinc and silver which are respectively tasteless, if applied one above, the other below the tongue, and there made to touch, occasion instantaneously a pungent metallic sensation in the mouth. The "*Theorie*" was published in 1758, and was fraught with a multitude of whimsical speculations we have neither space nor inclination to notice.

We next find it stated that in 1786, a student in the dissecting room of Bologna, having been bitten by a mouse, seized the culprit, killed him, and proceeded to dissect him. In doing so, while tracing one of the nerves with the point of his knife, he received a shock which benumbed his arm. The fact excited much attention, and was aptly compared to the effects produced by the torpedo and electric eel. No result of value, however, proceeded from the occurrence.

Louis Galvani, to whom in reality the origin of this branch of science is attributable, was born in Bologna in 1737, and was educated for the medical profession. Long before his grand discovery, he was distinguished by his success as a profound anatomist. In 1790, during one of his anatomical experiments at which his wife was present, she noticed that convulsions took place in the limbs of some dead frogs, which

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* From the author's "*Notes of Lectures*" on Galvanic Electricity.

were placed on a table near an electrifying machine, whenever a spark was taken from the conductor by a person touching the frog with the point of a knife.

Although this circumstance depends altogether on an effect in common electricity, well known at a much earlier period, nevertheless it led to the institution of the experiments by Galvani, to which this branch of physics owes its existence. He soon found that by the simultaneous contact of different metals with the muscles and nerves of frogs, fishes, rabbits, and other animals, convulsive movements of the muscles were occasioned.

It would be premature to enter on the theory he formed to account for these remarkable effects, and which time and the progress of science have completely subverted. Suffice it to say, that his views were warmly opposed by the illustrious Volta, who in 1797, published the results of his numerous experiments in the XIVth vol. of the *Giornale fisico-medico* of Brugnatelli, having however seven years previously, addressed an account of his discoveries and apparatus to Sir Joseph Banks, then President of the Royal Society of London.

The first regular apparatus was that invented by Volta, and still called Volta's pile. It consists of a number of plates of copper and zinc, of which two were joined together, then a piece of pasteboard placed above, having been previously soaked in salt water or dilute muriatic acid. Similar sets were piled on each other, observing the same order throughout, that is, that all the zinc surfaces, and copper surfaces should present in the same direction. Ingenious as was this arrangement, smart shocks and faint sparks were the only effects it induced. The Medical College possesses an instrument of this kind of 200 disks, 3 inches in diameter, and the effects are far inferior to those of a modern arrangement not larger than a single disk of this series.

Volta about the same period also constructed the apparatus called the "crown of cups." It was composed of sets of zinc and silver rods soldered together, and bent into an arch, so that the ends of each pair dipped in separate glasses, containing very dilute acid. In this arrangement the zinc of one couple occupied the same glass with the silver of the second, and so on. The first zinc and last silver were not immersed, but were attached to copper wires ending in gold points. These wires were called the *conductors*, and their ends the poles of the battery.

In 1800, Messrs. Nicolson and Carlyle of Woolwich, made the remarkable discovery of the decomposition of water by this new agent. These experimentalists found that when the gold or platinum terminations of the battery were immersed in water at a moderate distance apart that a stream of gas issued from each point. The gases were collected separately, and found to be hydrogen and oxygen, the former in the proportion of two measures to one of the latter. Each gas was uniformly given off at the same side of the battery, and although very minute quantities only were obtained, their distinctive properties were unequivocally ascertained.

In the same year Mr. Carlyle further decomposed several neutral salts, for instance, the sulphate of soda, and found that the acid went to one pole, the alkali to the other, the order being constant. He further noticed that oxygen and the acids, were given off at the same side, and hydrogen and the alkalies at the other.

In 1801, Mr. Cruikshanks of Woolwich, constructed the trough battery which bears his name, and of which specimens may be seen in all cabinets of philosophical instruments. It consists of a trough of wood rendered water-tight by cement, and subdivided by metallic plates into cells half an inch broad. Each plate was formed of a zinc and copper plate soldered together by their surfaces. All the zinc surfaces were disposed in one direction, all the coppers in the opposite one. This battery was charged either with a solution of sal-ammoniac or with very dilute muriatic acid. Though superior in power to the previous forms of apparatus, it still gave very insignificant results. It was imitated, with slight modifications, by several experimentalists. The plates, for example, were attached to a movable wooden bar, so that they could be immersed in the cells, and removed from them simultaneously without delay.

Soon after this period, Sir Humphrey Davy commenced his memorable researches. His first important discovery was that electric arrangements might be made by single metals having two surfaces, each acted on by a different chemical agent. He succeeded in decomposing ammonia, nitric acid, and several salts. In all these experiments the acid formed round the wire corresponding to the zinc surface, and the alkali round the wire of the copper surface. By various experiments it was found that the former was in an electric state similar to that of *positive*, while the copper-surface answered to the *negative* common electricity. But the discovery which rendered Davy immortal, was his succeeding in decomposing by the galvanic battery the alkalies, potash and soda, and proving these to be compounds of oxygen with metals of the most extraordinary properties. These metals are lighter than water, take fire on its surface; nay, that obtained from potash inflames when brought into contact with ice. Pursuing this superb train of discovery, he decomposed, and obtained similar metals from lime, magnesia, and other earthy bodies. The battery with which these wonderful results were obtained consisted of 2000 couples of zinc and copper, each plate four inches square, arranged in porcelain troughs, and acted upon by dilute sulphuric and nitric acids. Besides its chemical effects it was found to give overwhelming shocks, to deflagrate and burn metallic wires, and that when its poles were tipped with charcoal their contact occasioned the ignition of the charcoal, and the emission of light of inconceivable brilliancy. On slowly separating the poles an arch of electrical flame, ¾ths of an inch long, extended between them, and on repeating this experiment in the vacuum of an air-pump the arch of flame could be lengthened to three inches, and it was discovered to be attracted or repelled by the different poles of a steel magnet brought into its vicinity.

This formidable battery however was too sudden and inconstant in its action to be used with the calmness essential for the complete investigation of the laws of the arrangement. Various attempts were therefore made to render the instrument more constant, and more manageable in the hands of ordinary manipulators.

The first great improvement introduced was by Dr. Wollaston in 1805. In his battery each element or couple consists of a rectangular plate of zinc, surrounded by a plate of copper at half an inch distance, and kept from contact by slips of wood. The zinc of one plate leads to the copper of the next, and so on through the whole arrangement. Ten couples form each set, and are attached to a wooden bar by which they are immersed in the corresponding cell of a porcelain trough.

Ten plates of this construction, each 6 inches square, suffice to shew the decomposition of water and of several of the neutral salts—to produce sparks—to ignite and fuse thin pieces of platinum or steel wire, and to occasion some magnetic effects which will subsequently be pointed out.

It having been ascertained about this period that increasing the *surface* of the plates increased proportionally the igniting and heating powers of the battery, a very remarkable arrangement was constructed by Mr. Children of London in 1815. His battery consisted of 20 spiral coils of zinc and copper sheets, the copper being 2½ feet broad and 6 feet long. The metals were kept from contact by horse-hair ropes.

Twenty of these couples were arranged in the usual way, the copper of one being connected with the zinc of the second, and so on. The whole of the coils were suspended from a beam, and lowered at pleasure into cisterns of dilute acid placed beneath them. The igniting effect of this arrangement was so great, that it fused bars of platinum ⅜ths of an inch thick.

All experimentalists were however surprised to find that it gave no perceptible shocks. This fact was soon followed out, and it was found that to affect the living system, or produce muscular commotions, a series of several small couples not larger than one inch disks are more effective than a few plates however enormous their size.

About this time, (1819,) Oersted of Copenhagen made the great discovery of the magnetic state of a wire connecting the elements of active galvanic circles. This discovery in itself opened out a wide field of science, and disclosed the existence of a new force previously unsuspected by philosophers. The fruitful applications in art and science to which it has led will give us an interesting object of study as we proceed.

Professor Hare of Philadelphia in subsequent years constructed several series of batteries on Children's plan, and succeeded with them in producing some remarkable effects. He was the first to shew how platinum wires could be ignited at a great distance, and even under water, and to propose the application of this fact to submarine explosions. The success which has attended the practical application of this plan to the destruction of sunken wrecks, and on the very largest scale, has been sufficiently shewn by the explosions conducted by Colonel Pasley, Captain Fitzgerald, and myself.

In 1832 and succeeding years, Mr. Faraday, in a series of masterly papers published in the Transactions of the Royal Society, investigated minutely many of the laws of the galvanic circle, added several most important facts to our knowledge, and enriched the nomenclature of the subject with numerous terms singularly expressive and appropriate, and since universally adopted. These terms will be quoted and explained as we proceed.

The first step towards accomplishing the desideratum of a constant battery was afforded by Mr. Kemp's discovery in 1829 of the remarkable fact, that amalgamated zinc is not acted upon by dilute sulphuric acid unless it forms part of a galvanic circuit. As most of the recent and extraordinary improvements in the battery depend upon this fact, we must endeavour to place it before the student in a plain and practical light.

Let a piece of well amalgamated zinc be immersed in a glass vessel containing sulphuric acid one part, water twenty. No action whatever occurs. Introduce a gold or platinum wire without touching the zinc, there is still no action. Let it touch the zinc, and immediately a copious stream of hydrogen gas issues from the wire. Water is decomposed the instant of the contact. Its hydrogen escapes from the platinum wire, its oxygen unites with the zinc, and immediately after on removing the platinum wire we find oxide of zinc in solution.

Or let the zinc and platinum be immersed in the same acid but not touching each other. Then let a wire touch each simultaneously out of the fluid, the same instantaneous decomposition of water occurs, and continues to take place so long as the metallic contact is established, ceasing the instant this is interrupted.

If a series of couples of platinum and amalgamated zinc be arranged on the plan of Volta's crown of cups until metallic contact is established between the first zinc and last platinum of the series, no action takes place on any of the zinc plates. On the contact being made decomposition of water proceeds in every cell, hydrogen is evolved on each platinum plate, each zinc plate is oxidized; and the measure of hydrogen is the same from each platinum, and the amount of oxide of zinc formed the same in each cell. All action ceases in the entire series when metallic contact is interrupted in any part of its course.

This arrangement would answer every purpose were it not for two objections. In the first place the sulphate of zinc (produced by an electrical action afterwards explained) deposits metallic zinc on the surface of the platinum plate, and all electrical action is thereby soon nullified, there being only zinc surfaces opposed to each other. Secondly, the hydrogen gas set free in bubbles from the platinum surface is found to intercept or prevent much of the electrical effect. After Kemp's discovery, there thus still remained these two capital faults before the galvanic battery could be deemed a perfectly manageable or constant instrument.

Mr. Mullins, M. P. for Kerry, was the first who succeeded partially in remedying these evils. In his battery a copper cylinder was surrounded by a bladder, outside which was placed an amalgamated zinc plate, the whole immersed in an earthen vessel. A series of any number of these was combined by leading a wire from the zinc of one to the copper of the second, and so on. The battery was charged by filling the copper cylinder with a strong solution of sulphate of copper, and pouring a solution of salt or weak sulphuric acid on the zinc outside the bladder.

In this battery no action occurred unless the first and last metals were united by a metal, by charcoal or by some conducting substance. Decomposition of water took place on the zinc side, and the hydrogen transferred through the bladder being set free on the copper side in presence of sulphate of copper reduced the oxide of that metal, which was accordingly deposited in thin bright layers on the surface of copper opposite to the zinc. An equivalent quantity of sulphuric acid also passed through the membrane from the copper zinc side, where it formed sulphate of the oxide of zinc. But though the membrane effectually prevented the passage of metallic *zinc* to the copper, it has always been found in practice with these batteries that the opposite fault occurs and copper is gradually deposited on the zinc. This constitutes their most serious defect.

Professor Daniell's batteries are nearly on the same plan. An amalgamated zinc rod is surrounded by membrane, and immersed in a copper cylinder containing a strong solution of sulphate of copper. The zinc is acted upon by dilute sulphuric acid.

Among the objections to the use of membranes is their rapidly spoiling and being corroded, and their not permitting the use of any but the circular or cylindrical form. To obviate these faults, I tried, in 1839, with full success, the use of tanned sheep skin, and subsequently of pasteboard. The use of this article gives us unlimited command over the form of the battery, while it is less troublesome and more lasting than membranes of any kind.

On this plan I constructed in 1839, two sets of batteries which require a cursory description.

One set consisted of 80 rectangular troughs 14 inches long, 13 deep, one broad. For each trough there was a corresponding zinc plate amalgamated and enclosed in a pasteboard case, the edges of three sides being fastened water-tight by slips of wood and copper screws.

Ten of these cells effected constantly a greater degree of chemical decomposition than would have been caused by treble the number of the previous arrangements. The igniting effects too were so powerful as to enable me to use this small number with confidence and success in the explosion of the wreck of the "Equitable" at Fultah Reach, in the Hooghly, on the 14th December, 1839.

The whole series of 80 constituted the most powerful battery then in existence. Its effects will be noticed in the sequel.

The second series above alluded to, consisted of 12 water-tight teak cisterns, each of an internal area three feet long, two deep, and three inches wide. Each cistern was provided with two copper partitions, at an inch distance from each other, thus dividing the cistern into three metallic cells each exposing 12 feet of copper surface. Between each pair of copper surfaces a zinc plate of corresponding size was introduced in a pasteboard case. Thick copper wires led from each zinc to the copper plates of the adjacent cistern. The battery thus exposed thirty-six feet of active surface in each cistern. It was charged by a strong solution of sulphate of copper in contact with the copper, and of sulphate of soda in contact with the zinc. The chemical, magnetic, heating, and igniting powers of this splendid instrument exceeded all I had ever witnessed or read of. They are described in detail in subsequent lectures.

We now arrive at the last and greatest step to perfection in this apparatus, by which the chief faults above pointed out are remedied, and which, while it opens prospects of still greater success, at once places the galvanic battery among the most constant, portable, manageable, and powerful of all the instruments which science has given to mankind.

Mr. Grove, an English barrister, is the contriver of this most original and valuable apparatus. The elements consist of amalgamated zinc and platinum, separated from each other by porous earthenware cells. In contact with the platinum is placed the strongest nitric acid. In contact with the zinc, a mixture of one part sulphuric acid and ten parts water.

No action whatever occurs in this arrangement till the extreme plates are united by a conductor. Water is then decomposed as in all the other cases—and its hydrogen being transferred through the porous earthen cells to the platinum is there intercepted by the nitric acid with which it gradually forms water, thus diluting the acid.

The platinum undergoes no change whatever—the battery is perfectly constant in its action. Its powers are so enormous, that by tests which will subsequently be explained, it has been proved that ten such couples, each four inches square, are equal in power to more than thirty-eight times that surface of the best previous construction of zinc and copper.

On this principle, using (for local reasons merely) gold instead of platinum, I have prepared a battery of forty-eight couples, of which the following is an exact description.

Each couple consists of two zinc cylinders and one gold cylinder, which with the porous earthenware vessel fit in a pint glass tumbler.

The gold cylinder is two inches broad, four deep, and is provided with a gold strap half an inch broad and three inches long. It is placed in the circular cell formed by the two concentric walls of the earthenware cylinder, and this is filled with the strongest nitric acid. In the centre is placed the small zinc, outside all the large zinc, and the straps belonging to these are bent in contact with each other, between them being placed the gold from the next cup, the contact being preserved by a little copper spring clasping the straps together like a finger and thumb. In contact with the zincs is poured the usual mixture of sulphuric acid and water.

In electric power this battery equals for equal surfaces those of Mr. Grove's platinum cells. The effects produced will be given in detail. I should mention here however that I have found by recent experiment that well gilt porcelain produces exactly the same effect as gold, and I have accordingly sent orders to France for fifty cylinders gilt at both sides, and each exposing two superficial feet. I have also found that a mixture of two parts by weight of sulphuric acid to one of saltpetre and two of water, gives as effective a liquid for the gold surface as the strongest nitric acid. These facts render the gold battery in construction as cheap as those of copper, and in sustaining action much more so, inasmuch as the expense of the mixture I describe is not more than one-third of that of the solution of sulphate of copper. The importance and utility of these facts will be apparent as we study in detail the effects of the galvanic agent.

The gold of the battery above described is worth about 500*l.*

NOTICE OF COMMON ELECTRIC EXCITEMENT——ON THE CHEMICAL EFFECTS OF SIMPLE AND COMPOUND BATTERIES.

When a piece of wax or a dry glass tube is subjected to friction on woollen cloth or silk, it is found to attract and repel light substances, such as feathers, dust, pith-balls, metallic particles, and the like. In studying these facts we further find that a substance attracted by the excited glass after touching the latter is repelled, while excited wax attracts it; or on the other hand whatever excited glass attracts, the wax repels. A great multitude of substances can assume this excited state, and if it agree in attracting power with that of glass it is termed *vitreous*, if with that of wax, *resinous*, electricity. Large surfaces of glass or resin subjected to friction by machinery are found to give powerful sparks, which pass suddenly with various tints, and often present the exact appearance of lightning on a miniature scale.

The electricity excited by friction may be conveyed by certain bodies termed *conductors* to great distances from the source of excitement. The metals, dry charcoal, dilute acids, and saline solutions, water, and moist air, are the best conductors; and among the metals copper holds the first place. The electricity which is being conveyed has been proved moreover to affect only the surface, not the mass of the conductor.

There are again numerous substances which refuse to convey electricity along their surface, and are therefore called non-conductors; or, being sometimes employed to confine it or restrain its progress, *insulators;* of these glass, sulphur, resins, lac, caoutchouc, silk, talc and oil of turpentine are the most remarkable.

The two opposite conditions we have described as *vitreous* and *resinous* are also termed *positive* and *negative*, on the idea that the phenomena of rubbed glass depend on an excess, those of excited wax on a deficiency of their natural electric matter. The fact however that two negatively electrified bodies repel each other, is in itself sufficient to disprove the latter hypothesis, inasmuch as it involves the conclusion that the particles of matter in the natural state are self-repellent.

When a substance *a* in a state of electric excitement is brought into the vicinity of a conductor placed on an insulating support, the part of the conductor nearest *a* is found to be electric, but in the opposite kind of excitement, while the part most distant from *a* is also electric, but the excitement is of the same kind. These phenomena are called *induction.* On withdrawing *a* all evidence of electrical activity ceases in the second body. But if we touch it at the part most distant from *a*, while under induction, a spark of the same kind of electricity passes to the finger, and then on removing *a* the second body remains in the active state, but in the opposite condition.

These facts have been applied to the accumulation and preservation of great quantities of electricity in the apparatus called the *Leyden phial.* This consists of a bottle having tin foil pasted on its inner and outer sides to within two inches of the top. A wire terminating in a ball is in contact with the outer coating, and rises above the bottle, passing through a piece of glass for its support.

On passing sparks say of vitreous electricity to *a*, the inner coating acquires the vitreous state, and acting by induction on the outer metallic coating *b*, the natural electricities of this are decomposed, the vitreous or positive is repelled to the outermost surface, the resinous or negative attracted to the surface next the bottle. The finger brought near the tin foil receives a succession of sparks, and on withdrawing the finger the jar remains charged, the inner coating being in the vitreous (positive), the outer in the resinous or negative state.

If any conducting body be interposed between *a* and *b*, the two electricities rush together, often with an explosion, and if an animal be the conductor, violent shocks are experienced. If the discharge be passed through a very fine wire it is melted and dispersed. It inflames various substances, and in short presents all the phenomena of lightning in a minute degree. It magnetizes steel needles if discharged *across* them, and by very careful management it effects chemical decomposition.

A series of Leyden bottles may be arranged so as to form a " Battery." This may be charged by the common electrifying machine, by the electric fluid attracted from the clouds, by electricity evolved from jets of high pressure steam, by magnetic instruments, and lastly by the *galvanic circle.* It may be charged to such a degree that the explosions resound like musketry, and take place with force sufficient to destroy the life of the largest animals.

This slight sketch of common electricity is essentially necessary for understanding the sequel of these notes. We now proceed to notice the chemical effects of the galvanic agent.

CHEMICAL EFFECTS OF THE GALVANIC CIRCLE.

Expt. 1. Take a single couple of amalgamated zinc and copper, excited by dilute sulphuric acid. Let a copper wire lead from each, terminating in a platinum point. Place a drop or two of water in the little glass capsule, and introduce the platinum points so as not to touch each other. No action takes place.

Expt. 2. Take one of the gold cells and dispose its wires similarly. There is still no action.

Expt. 3. Add a drop of sulphuric acid to the capsule, or a minute crystal of salt (common or Glaubers salt) and again try the first couple. There is no effect visible. But with the gold and zinc couple, a stream of gas rises from each of the platinum points.

Expt. 4. Repeat experiment 1st, with a single cell of any size (say one of the thirty-six feet cells of the College battery). The same effect is observed.

From these experiments we conclude that the decomposing force of a single cell is not in proportion to its surface or size, but to the energy of electric action within it; and secondly, that water containing a little acid or saline matter is decomposed under circumstances when pure water is not affected.

A single cell of whatever size or construction has indeed but very faint decomposing force. The whole of the gold battery of forty-eight cells can be arranged so as to act as one cell, and still this occasions little greater chemical action than $\frac{1}{48}$th part of the series would accomplish.

Let us now see the effect of adding to the number of cells, and confine ourselves at first to the study of the decomposition of water. For these experiments the following apparatus is occasionally used. It consists of a glass cup with two inverted tubes, to be filled with water slightly acidulated, and placed over strips of platinum foil, which can be connected with the ends of the battery outside. The gas evolved passes into the tubes.

Another and far superior instrument consists of a glass jar to which a cork and bent tube are attached. Two platinum or gold plates (the gold must be perfectly pure) are introduced, with straps or thick wires of the same metal led (air and water tight), through the sides of the jar. The jar is filled with water acidulated with sulphuric acid. On making connexion with the battery decomposition rapidly occurs, and the gas produced is delivered by the tube into a graduated jar standing over water, and thus the quantity produced in a certain time is measured with the greatest ease.

The following table shews the effect of increasing the number of couples in the battery. The apparatus used was a series of three hundred cells on Mullins' construction. In each experiment the gas was collected for three minutes.

Number of cells.		Gas obtained in cubic inches.
1	....	no effect.
2	....	0.30
4	....	3.90
6	....	6.00
8	....	6.60
10	....	7.80
12	....	9.00
14	....	9.60
16	....	9.90
18	....	10.20
20	....	10.50
22	....	9.60

Number of cells.	Gas obtained in cubic inches.
32	9.00
42	7.50
52	6.90
62	6.90
86	6.90*
106	7.80*
146	8.10*
300	7.80

* The increase here was owing to the temperature of the battery becoming higher from the heat of the day.

Thus beyond the tenth additional pair the chemical force of this battery did not increase with any number of additions.

In another set of experiments the rectangular cell battery similarly charged was employed. The surface of each zinc plate in this arrangement is greater than that of the last experiment. The time was the same, three minutes for each trial.

Number of cells.	Cubic inches of gas.
1	0.00
2	2.50
3	5.20
4	9.00
5	12.00
6	24.00
7	31.00
8	40.00
9	43.00
10	46.20
11	48.00
12	50.10
24	56.00
30	58.00
40	59.30
60	61.70
80	62.00

These experiments shew that increase of surface of each cell increases proportionally the decomposing force, but that no *proportionate* increase resulted from adding to the series of these cells beyond the sixth of the series.

The same experiment was tried with the thirty-six feet cistern battery.

Number of cisterns.		Gas obtained in 3 minutes.
1	....	0.00
2	....	7.00
3	....	21.00
4	....	43.00
5	....	74.00
6	....	140.00
7	....	210.00
8	...	220.00
9	....	220.00
10	....	224.00
11	....	225.00
12	....	227.00

Here we again observe beyond the seventh addition no proportionate increase of decomposition. In this experiment too we observe a smaller quantity of gas formed than we might expect from the immense size of the plates. This proceeded however chiefly from the inadequacy of size in the decomposing plates of the voltameter, which must always be enlarged in proportion to the size of the galvanic or active surfaces.

Lastly, with the gold battery we have found the following results :—

Gold cells.		Cubic inches in 3 minutes.
1	....	a trace.
2	....	3
3	....	11
4	....	18
5	....	21
6	....	23
7	....	27
8	....	30
9	....	32
10	....	32
12	....	34
14	....	37
16	....	39
18	....	39

Gold cells.		Cubic inches in 3 minutes.
20	....	39
25	....	40
30	....	41
35	....	42
40	....	42
48	....	42

Thus this battery is for an equal number of cells (four of Mullins') five times more powerful than one of six times greater surface, but it still shews the influence of the same law, that beyond the addition of a few couples the decomposing effect is not proportionately augmented.

It is now time to draw the reader's attention to what occurs in the voltameter battery itself during the decomposition of water in the apparatus.

We have already described the composition of water, and must now repeat that nine grains of water contain eight of oxygen and one of hydrogen gas, and that nine grains of oxygen at common temperature and pressure measure, 26 cubic inches, and one grain of hydrogen 52 cubic inches. Thus 78 inches of gas in the voltameter shew that one equivalent of water has been decomposed.

I have already explained that decomposition of water occurs in each of the battery cells, and that oxide of zinc is formed and dissolved by the sulphuric acid. Now it is found by experiment that for every equivalent of water decomposed in the voltameter thirty-two grains of zinc are oxidized and dissolved from every zinc plate in the series.

Thus in the experiments with the eighty rectangular cells, 8 plates decompose an equivalent of water in 6 minutes, at the expense of 8 equivalents of zinc or two hundred and fifty-six grains. But eighty cells only effect this decomposition in about 4 minutes, and at the expense of eighty equivalents, or two thousand five hundred and sixty grains of zinc.

This most important law was discovered by Mr. Faraday in 183 , and it applies to every form of battery yet invented. It may be thus expressed: "For every equivalent of a compound decomposed in the voltameter an equivalent of zinc is corroded from every zinc in the whole series."

Various circumstances may *increase* the expenditure of zinc, but it seems that less than the equivalent cannot under any circumstances be consumed from each plate.

The best, most powerful, and cheapest chemical battery therefore is that which with fewest alternations of zinc decomposes an equivalent of water in the shortest time.

It is here necessary to observe that in those forms of apparatus in which more than one zinc plate is used in the same cell, provided these plates be in metallic contact they act as one. Thus the three large plates in each of the teak cistern batteries, and the two of the gold cells being connected together act as one plate. The loss of zinc therefore from the three great zincs is one-third of an equivalent from each, and from the two zincs of the gold battery, half an equivalent from each.

We learn further from the voltameter that within certain limits increasing the surface of the plates increases in direct proportion the decomposing power of a given series. Thus four of the gold cells evolve 18 inches of gas in one minute. If we then join all the zincs of two cells together, and also unite the golds, and then connect four of these double cells in the usual order, the result is exactly doubling the decomposing power, or in other words, obtaining 36 inches of the mixed gases.

This holds exactly true as far as two feet active surface in the gold batteries, and six feet in the copper arrangement. Beyond that the subject is still open to investigation. In the following tables are recorded the results of experiments on this point conducted with batteries of Mullins' and my own construction.

My first experiments consisted in introducing a second cylinder of zinc covered with a membrane, into the copper cylinder of Mullins' battery. Both surfaces of the copper were thus called into action.

The following was the result of the comparative trial :—

Single zincs, surface	60 inches,	in 3 min.	gave	10 in. gas.
Double zincs, ...	120	 3	....	20 do.

Following up this observation, a battery of 12 cans, each consisting of three concentric coppers and two concentric zincs, each plate provided with a membrane, was constructed so that the series of coppers exposed a surface of 240 inches. Again the decomposing force was exactly doubled, thus :

Single zinc cans, surface	60 in.	in 3 min.	gave	10 in.
Double ditto, ...	120	3	....	20
Concentric nest, ...	240	3	....	40

With the rectangular batteries, a copper partition 16 inches by 14 was introduced into the middle of each cell, and a zinc plate placed at each side. The surfaces were thus doubled, and the effects were immediately doubled also.

5 single cells gave	13 inches	in	3 min.
5 partitioned do.	30	....	3
8 single do.	35	....	3
8 double do.	70	....	3

Twenty-four single cells were now arranged, so that they constituted eight sets. Thus every three copper cells were placed in metallic contact, and the wires of every three zincs led to the adjacent triple copper.

These eight triple cells gave in three minutes, 106 cubic inches, the exact arithmetical ratio which tripling the surface should occasion.

Influence of temperature on the decomposing force.—This point is of so much importance, that it requires full experimental illustration. The following results I repeat from a paper I published on the subject in this Quarterly Journal of the Medical Society of Calcutta, 1838.

The temperature of the period during which my first experiments on this subject were carried on, viz. from the 10th April to the 30th of June, ranged from 84° to 100° Fahr. in the room where the batteries were used.

The daily variation of power in Mullins' constant battery with new plates, and strong solutions, was from 5 to 7 cubic inches, from 10 A. M. to 4 P. M.

The range of effect in a large rectangular battery subsequently described, was 33 to 42, during the latter end of July and whole of August, while the Thermometer in the laboratory varied from 78° to 92°.

To ascertain the effect of artificial changes of temperature, the following experiments were tried :—

On the 16th August I placed in a cistern of water a battery of eight rectangular cells, which in air and in water at 88° evolved at its poles 22 inches of gas in three minutes. By adding boiling water in successive portions to the cistern, the temperature of the battery was gradually raised, and its decomposing powers tried. With every increment of temperature the force of the battery augmented, and at 130° Fahr. it was more than doubled as is seen in the annexed table.

Temp. of battery.		Gas evolved.		In
86	....	22 cub. inches.		3 min.
90	....	27	....	3
93	....	31	....	3
97	....	34	....	3
102	....	36	....	3
105	....	39	....	3
107	....	40	....	3
120	....	45	....	3
130	....	48	....	3

The warm water was now drawn off and the battery allowed to cool gradually. The force proportionately and regularly fell. Thus :—

Temperature.		Gas evolved.		In
126	....	40 cub. inches.		3 min.
120	....	39	....	3
116	....	36	....	3
112	....	35	....	3
92	....	30	....	3
86	....	24	....	3

In these experiments then we find, that the range of heat from 84° to 102° is more than sufficient to produce the daily variation of galvanic power I have noticed.

On the 17th August these experiments were repeated with a more powerful battery, and the preceding results were thoroughly verified; thus:—

The battery employed consisted of 8 rectangular cells, of the same dimensions as in the preceding experiment, but having newly amalgamated zinc plates.

Temperature of the battery.	Gas evolved.	In
80	40 cub. inches.	3 minutes.
83	46	3
96	80	3
100	93	3
130	120	3
140	136	3
150	159	3
160	180	3

The battery in these experiments was heated by immersion in water. Those who are conversant with galvanic phenomena would have been gratified to witness the effect produced by so small a battery. It occupied little more than a cubic foot of space. Its heating and deflagrating powers were great in proportion to its chemical force. On making and breaking contact with its wires, sparks half an inch long and of dazzling brightness passed with a report like the discharge of a large Leyden battery. It ignited 3 feet of iron wire $\frac{1}{10}$th of an inch in diameter, and fused into a boiling liquid two inches of a thick rat-tailed file.

To complete the evidence of the effect of heat on the battery, the converse of the preceding experiments was tried.

Influence of cold.—Eight cells of the same dimensions as those used in the former experiments were arranged with new zincs, fresh solutions, and new leathers, under circumstances in short, all calculated to promote galvanic action. The decomposing power of this battery in air and water at 84°

was found to be equal to 40 inches of the mixed gases in three minutes. The temperature was then gradually lowered by the addition of ice to the water surrounding the battery, when the following effects were observed:—

Temperature.		Power of battery.		Time.
84	....	40	....	3 minutes.
79	....	38	....	3
73	....	35	....	3
69	....	32	....	3
65	....	30	....	3
62	....	30	....	3
60	....	28	....	3

The battery when cooled to 60° had been at work two hours. The cold water was then drawn off, and without disturbing the battery this was allowed to regain the standard atmospheric temperature, which it acquired in one hour and forty minutes. Its power was then tried, and found to be 39 inches of gas, being within one inch of the quantity it produced at the same temperature at the commencement of the experiment four hours before.

It is a curious circumstance, that the liquid in the decomposing cell is not similarly influenced by changes of temperature. A pair of platinum poles were introduced into a retort half filled with acidulated water. A battery being connected with these plates, evolved six inches of gas in three minutes at 90° Fahr. The liquid was then raised to the boiling point, and still six inches were the product. Allowed to cool and then introduced into a freezing mixture till brought to 40°, the same quantity was still obtained.

These experiments have since been repeated, and verified by Professor Daniell, of London.

It is however a very extraordinary fact, that increase of temperature does not produce the same effect on the gold battery. It seems that in this the affinities in play have at common temperatures reached their highest activity.

It should be mentioned here, that the approach of storms, especially from the northwest has a strong, but unexplained, power of increasing the decomposing force of the battery. The increase has been as much as one-third in several experiments I made in 1839.

Diminishing the pressure of the atmosphere on the surface of the battery cells retards rather than promotes their energy.

The decomposing bottle, plates, and liquid may be placed in vacuô, or subjected to increased pressure to the extent of three atmospheres, without the least difference occurring in the amount of the decomposition.

We have now a sufficient idea of the nature of the chemical force of the battery, and of the mode in which it is best directed. We have found too that a few plates are proportionately more powerful than a numerous series. We have next to attend to the powers of the decomposing plates when other substances than water are under their action.

There are in nature fifty-five elementary bodies, of which four are gases or airs, twelve non-metallic solids or fluids, and the rest metals. Of these it has been proved that oxygen, chlorine, fluorine, iodine, and bromine always during decomposition appear at the plate which corresponds to the positive side of the battery, while hydrogen, and the metals are evolved at the side corresponding to the negative pole of the arrangement. The relations of phosphorus, carbon, nitrogen, and sulphur are less understood. When saline bodies are decomposed the acid goes to the zinc, the alkali or oxide to the copper side. This constancy of attraction led Sir H. Davy and others to investigate the electric nature of the extremities or poles of large galvanic series, and it was found that the copper end gave unequivocal proof of vitreous (positive), the zinc end of resinous (negative) excitement. Now as dissimilar electric bodies attract, and similar repel each other he termed oxygen, the acids and those bodies of that class "Electro-negative," as they were attracted by the positive pole—and hydrogen, the alkalies, oxides and metals he called "Electro-positive" as these were attracted by the negative pole.*

The terminations of wires connected with the extremities, and which were formerly called "Poles," Mr. Faraday terms "*Electrodes*," or the paths for the electrical discharge. The positive pole he names the *anode* or entering path, and the negative he calls the *cathode* or descending or departing path. The fluid under decomposition he names the *Electrolyte.*

In effecting chemical decomposition (electrolysis) there are certain conditions of the electrolyte without which its elements (*ions* as Faraday terms them) cannot be separated.

First. The compound must be either in solution or fusion. For instance, water if frozen not only resists decomposition, but completely prevents all circulation of the electric force.

Secondly. The electrolyte must be a conductor of galvanic electricity. Thus turpentine and the liquid resins, which are non-conductors, are not decomposable by any number of cells. Water in the pure state conducts but feebly, and is very difficult of decomposition, but on adding a little sulphuric acid its conducting power being increased, it is decomposed with proportionate facility.

Thirdly. It is established by Faraday's experiments, that it is only those compounds which consist of one atom of each of their constituents, viz., protoxides, proto-chlorides, proto-iodides, &c. which undergo *direct* decomposition. But there are again many such compounds which cannot be electrolyzed.

Fourthly. The electrolytic power of a battery of any given size depends on the power of each cell in the series, and

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* *Within* the battery the zinc is positive, the gold, platinum, or copper, negative. Thus the zinc is oxidized and the hydrogen goes to the opposite metal. But when a series of plates are arranged and connected with poles *outside* the battery, the pole belonging to the zinc end is *negative*, and on this hydrogen, the alkalies and metals are obtained; while the pole of the gold, copper or platinum oxide is positive and yiel s oxygen, chlorine, iodine and the acids.

if a cell from any cause fails in its action, the whole force of the entire series falls to the same degree. Thus if in a battery of 12 plates 144 superficial inches each, the decomposing power being equal to thirty inches of gas in three minutes, if for one of the plates we substitute one of seventy-two inches surface, the decomposing power of the whole twelve falls at once to fifteen inches of gas in three minutes.

Fifthly. In decomposing a compound it is essential for the transfer of its constituents to either electrode that each element shall find another to combine with it chemically along the whole line between the electrodes. Thus, if we place the positive electrode in a solution of sulphate of magnesia and pour distilled water carefully over this, and into the distilled water place the negative electrode, the sulphate of magnesia will be decomposed, its acid be evolved at the positive electrode, but the magnesia be deposited in the solid state at the line of contact between the saline solution and the distilled water. Magnesia being insoluble in water, cannot find its way through that fluid to the negative metallic electrode.

It is necessary too to distinguish between the effects of *direct* and *secondary* decomposition.

By *direct* decomposition is meant the evolution of each element of a compound in the state in which it first entered into combination. Thus binary compounds, such as water, chloride of lead, &c. give up their elements at either electrode. But when compound bodies or mixtures of various electrolytes are used, the elements of these frequently react on each other, and new and often unexpected forms of matter present themselves at the electrode.

Thus when a solution of sulphate of oxide of copper in water is decomposed, we find the water and the salt are simultaneously electrolyzed. The acid of the salt and oxygen of the water are evolved at the positive or anelectrode, and we might expect the hydrogen of the water and the metallic oxide to appear together at the cathelectrode. Such however is not the case. The oxide of copper and hydrogen at this electrode react upon each other by ordinary affinity, the hydrogen and oxygen unite and form water, and the metal is deposited in the pure state.

All the metals which are incapable of decomposing water under ordinary circumstances, may be thus obtained from solutions of their salts. Gold, silver, copper, tin, lead, iron and platinum are thus procurable, and usually in a highly crystalline state.

The metals which decompose water at common temperatures, for example potassium and sodium, cannot be obtained from the watery solutions of their salts.

If the electrode be of a metal which can combine directly with the substance evolved upon it in electrolysis additional phenomena of interest occur.

Thus if gold or platinum be made positive in a solution of common salt (chloride of sodium) the chlorine combines with the gold or platinum which is corroded and dissolved. If silver be positive in this solution, the white chloride of silver is formed on the surface of the plate.

As platinum and gold are not corroded by ordinary acids or alkalis, these metals are preferred in the electrolysis of all compounds not containing chlorine. The ordinary metals, copper, tin, iron, lead, zinc, &c., all become oxidized and dissolved at the positive electrode when watery solutions of oxygenized salts are decomposed. Some very beautiful experiments may be performed by making various metals positive in neutral solutions of saltpetre (nitrate of potash) and mixing with this solution a few drops of the tests of the different metals.

Expt. 1. Place an iron wire in a solution of saltpetre mixed with a little tincture of galls. The liquid in contact with the iron is rapidly converted into *ink* on the battery circuit being completed. The iron should be positive.

Expt. 2. Use similar solutions and apparatus, but for tincture of galls substitute a little of the yellow salt called prussiate of potash. Apply the battery, and Prussian blue is immediately formed round the iron electrode.

Expt. 3. Mix a solution of starch with one of ioduret of potassium, a colourless transparent salt. Use platinum electrodes and the same apparatus as above. Iodine is set free at the anelectrode, and acting on the starch gives it a fine blue colour.

Expt. 4. Use the solutions of the first experiment and a leaden anelectrode; add a few drops of chromate of potash or ioduret of potassium dissolved in water; the yellow ioduret or chromate of lead is formed when the battery is applied.

Expt. 5. Use a solution of common salt (chloride of sodium) tinged blue by indigo previously dissolved in sulphuric acid; let the electrodes be platinum. Apply the battery, and the instant liberation of chlorine at the anelectrode bleaches the indigo solution.

The common operation of chemical affinity may in many instances be resisted or turned aside by electric forces. Sir Humphrey Davy's memorable attempt to protect the copper sheathing of ships from corrosion by sea-water affords a good illustration of this kind of interference with ordinary affinity. The copper is corroded chiefly by the chlorine of the sea salt. Sir Humphrey Davy found that by attaching small pieces of zinc or iron to the copper the latter was completely protected by being thrown into the negative electric state, while the chlorine and oxygen of the sea-water were evolved on and corroded the zinc or iron protector.

Silver or copper may thus be introduced into strong nitric acid and no solution of the metals occurs, so long as by the association of a more positive electrode these are kept in the negative state.

It has been lately found by Becquerel, Cross, Fox, Bird, and others, that by the long continued use of low galvanic powers several very interesting compounds may be formed, which no other process will afford. Of these many are identical with natural minerals and gems. They are formed by the slow action of very weak batteries on solutions containing silica or flint and various earthy or metallic bases; minute crystals of different silicates are thus gradually formed about the positive electrode. The crystals are usually microscopically small, and thus the experiments lead to no hope of our being enabled by this method to manufacture gems, the possibility of which is now a matter of popular belief.

I shall conclude this notice of the chemical powers of the battery by a few hints to those slightly acquainted with practical chemisty, on the extemporaneous preparation of some useful and interesting substances by this apparatus.

Expt. 1. Procure a porous earthen-ware bottle, (air-tight,) introduce a platinum or gold plate, and fill the bottle with dilute sulphuric acid. Let the platinum plate have a wire or strap protruding through the cork which is perforated and provided with a bent tube for delivering gases. Place the arrangement in a tumbler containing dilute acid. Apply a battery of twelve cells, and let the inner plate be in connexion with the gold or copper side. Oxygen gas is given off freely in a state of perfect purity.

Expt. 2. Reverse the battery wires, so as to connect the inner plate with the zinc side. Hydrogen gas is now obtained.

Expt. 3. In a similar apparatus use a strong solution of oxalic acid, a compound of two equivalents of carbon and three of oxygen. Make the inner cell positive, and carbonic acid (carbon one equivalent, oxygen, eq. two) is liberated. If the inner cell be negative carbonic oxide is obtained.

To obtain chlorine charge the inner cell with muriatic acid and use a platinum electrode, make this positive and chlorine is abundantly set free, and may be collected over warm or salt water.

In concluding this notice of the chemical powers of the galvanic battery, I may observe that the chief object to be gained in this department is its application to the cheap supply of oxygen and hydrogen gases by the decomposition of water. Within the last year the experiments of Grove and those I have myself carried on, have made much progress towards the accomplishment of this object. If this be once effected we have at our disposal the most powerful of all agents for producing concentrated heat, and a force applicable to machinery far superior to steam in any of the present modes of employing that mover. The heat and expanded vapour suddenly produced by exploding twenty-eight cubic inches of oxygen and hydrogen (obtained by decomposing three grains of water) is sufficient to propel a 12lb. shot to a vertical height of twenty-three feet in less than one second of time. By the simplest machinery this immense power is made to act without any audible explosion; in its nature it is moreover so manageable that it can be directed with the most complete safety and ease.

APPENDIX.

PART II.

DETECTION OF POISONS.

The subjoined instructions are collated from a series of Reviews I published in the *Lancet*, Vol. I. 1830-31, entitled "Practical Commentaries on Dr. Christison's processes of the detection of poisons." To these papers I now append such improvements in medico-legal analysis as the progress of science has pointed out.

THE MINERAL ACIDS.

The sulphuric, nitric, and muriatic acids, usually demand investigation under three different conditions. In the first place, when after administration, whether in suicide, murder, or mistake, a portion of the pure and undiluted liquid remains for examination; secondly, when having been taken into the body, they become the subject of analysis in a state of admixture with the contents of the stomach, or vomited matter; thirdly, after aspersion on the body or apparel.

"Of the common properties of these acids, Dr. Christison speaks in the following appropriate terms:—

"The only common properties that require notice are, the power of reddening the vegetable blue colours, for shewing which litmus paper is commonly used, and is most convenient; and their power of corroding all articles of dress, especially such as are made of hair, wool, and leather. This last property is specified, though a familiar one, because it always forms an important piece of evidence in criminal cases. In order to apply it with accuracy, it is necessary to remember, that if the article of dress is a coloured one, it is generally rendered red by the mineral acids; but that the vegetable acids will also redden most articles of dress, although they do not corrode them."

Dr. Christison next proceeds to give directions for the detection of the sulphuric acid in its pure and diluted form:—

"When concentrated, it is oily-looking, colourless, or brownish, without odour, and much heavier than water, and it rapidly corrodes animal substances. If from these properties, and its effects on litmus, its exact nature is not obvious, it is to be converted into the diluted acid; in doing which the experimentalist will remark, that the mixture becomes very hot, if the water is not added too abundantly. When diluted, it is to be tested with litmus and tasted. An acid having thus been proved to be present, a little nitric acid is to be added, and subsequently a solution of the nitrate of baryta. If a heavy white precipitate falls down, it can be nothing else than sulphate of baryta, because no acid but the sulphuric forms with the barytic salt a white precipitate insoluble in the nitric acid. The phosphate and carbonate of baryta are both soluble in nitric acid. In applying this test, care must be taken to employ nitric acid entirely free from sulphuric, an admixture which the common nitric acid of the shops almost invariably contains."

The author also suggests the further examination of this precipitate by the following ingenious and satisfactory experiment:—

"Collect the precipitate on a filter, wash, dry, and remove it, then mix a little of it (not more than two grains) with a small proportion of dry charcoal powder, and subject the mixture for two or three minutes in a covered platinum spoon, or in a fold of platinum foil, to the flame of a spirit lamp, enlivened with the blow-pipe. A portion at least of the sulphate is thus converted into sulphuret of baryta. To prove this, put the powder with a little water, in the bottom of a small glass tube, add a little hydro-chloric acid, and then hold within the tube a bit of white paper, moistened with the acetate or nitrate of lead—sulphuretted hydrogen gas is disengaged, which will darken the paper, and likewise often betray itself by its singular odour."

In the consideration of these processes there are two circumstances which demand rather more particular detail; the first is, the adulteration of nitric acid with sulphuric acid; the second relates to the mode of obtaining the evidence of these properties from the smallest possible quantity of the barytic precipitate. With regard to the former, it is quite evident, that, should the nitric acid employed to test the solubility of this precipitate itself contain traces of the sulphuric, a quantity of sulphate of baryta should thus be formed and remain undissolved. The method of remedying this defect is exceedingly simple; it consists in the addition of a *dilute* solution of nitrate of baryta to the nitric acid, and allowing any precipitate which may occur to subside, and then removing the supernatant fluid. As to the second, attention is requested to the following experiment. A phial containing the acid, was inverted, and its contents allowed to escape; in this position it was suffered to remain for forty-eight hours, till it was apparently dry; on close inspection, however, an extremely minute quantity of moisture, not exceeding the 100th part of a drop, was seen in the angle between the bottom and sides of the phial; by touching this with the extremity of a small glass tube, drawn out to the fineness of a hair, the fluid immediately rose by capillary ascent, and was easily removed to a bit of thick glass; it was then touched with an equal quantity of nitrate of baryta, previously mixed with a sufficient quantity of nitric acid, when a white precipitate was immediately procured. On heating the glass, the sulphate of baryta remained in the form of a white crust, certainly not more than the 50th part of a grain in weight. This was, however, decomposed by mixing the crust on the glass with an equal quantity of charcoal, and heating it for a minute or two in a fine blow-pipe flame. The black colour of the charcoal soon disappeared, and after the glass had cooled, a minute drop of the solution of the acetate of lead, strongly acidulated with acetic acid, was dropped on the surface of the precipitate, when a deep-black stain of the sulphuret of lead was immediately produced. It is to be observed here, that the acidulation should always be with the acetic acid, since the nitric dissolves the sulphuret of lead, and a white precipitate is produced by the muriatic, which entirely obscures the effect.

I shall next quote Dr. Christison's directions for the examination of the contents of the stomach, vomited matters, and suspected stains, and also his opinions concerning the several fallacies to which the processes are exposed:—

"In the case of the contents of the stomach, vomited matter, or stains, the process is nearly the same as that for detecting it in its undiluted state. The suspected matter is simply to be boiled for a few minutes, distilled water being added, if it is a fragment of cloth or other solid; and after filtration, the fluid is to be subjected to the succession of tests mentioned above. The nitric acid, in the present process, has a double use. Besides keeping the carbonate of baryta and all other barytic salts, except the sulphate, in solution, it greatly favors the separation of the sulphate, and whitens it.

"But it may be said, that it is liable to fallacy when the acid is neutralised, for most organised bodies, and particularly the secretions of the stomach, naturally contain sulphates which will yield the required precipitate. This fallacy can be obviated in the instance of the contents of the stomach, or matters of vomiting, only by limiting the inference in favor of poisoning to the cases in which the precipitate formed with the nitrate of baryta is considerable. In the instance of stains on clothes, however, we have a surer corrective in a comparative analysis of a sound portion of the same clothes. Thus, in the case of Euphemia Macmillan, Dr. Turner and I procured, from a corroded piece of a hat, 4-3 grains of sulphate of baryta; and from a sound piece of the same size, a scanty precipitate, too small to be collected; from a stained piece of a coat, 0·9 of a grain of the sulphate; and from an unstained piece, close beside the other, a faint haze, but no precipitate."

In the analysis of the impure animal fluid, there is a precaution to be observed respecting the use of the nitric acid, that it should be invariably added *before* the solution of baryta, and the fluid allowed to stand for some time, for the following reason; in several animal fluids nitric acid causes a white albuminous, or caseous precipitate, *insoluble in that fluid*, and which by an inexperienced analyst may readily be mistaken for the sulphate of baryta itself. If, therefore, the *previous* addition of nitric acid cause a coagulation, filtration should be employed before the nitrate of baryta be applied.

With respect to the fallacies Dr. Christison so correctly mentions, we believe we can point out two other sources of deception of considerable importance; the first rather fortuitous, the second more constant in its operation; we allude to the medicinal employment of sulphur, and the sulphates of soda, potash, and magnesia. That sulphur, strange as the fact may appear, is liable to be converted into sulphuric acid in its transit through the mysterious laboratory of the digestive and excretory organs, has been indubitably proved by the experiments of Wöhler and Stehberger, as far as regards the urine, and by our own observations in a series of extended experiments on the contents of the alimentary canal. Again, it is a matter of notoriety, that in a majority of cases of sudden illness in town and country, a "dose of salts," whether Glauber or Epsom, is administered before the arrival of the medical attendant. A case may, therefore, be readily supposed to occur, in which a person may die of a sudden and suspicious illness, during which salts had been freely given; the contents of the stomach are examined, litmus paper is reddened (we apprehend that the operator will not usually taste such a fluid to examine its acidity any further), and on the addition of the nitrate of baryta and nitric acid, the precipitate is formed in great abundance. Under such circumstances, according to Dr. Christison's directions, if they be implicitly followed, the examiner should swear to the detection of sulphuric acid. Of course we confine ourselves, with Dr. Christison, to the *chemical* evidence, and do not take the morbid appearances into consideration, for these are so striking, as in some degree to supersede the necessity of an analytic examination at all. In all cases, therefore, we believe it will be essential to the chemical proof of poisoning of this kind, that no sulphur, nor sulphates, should have been administered for some time before death. We may here add, that Dr. Christison, in another place, relates a case in which the sulphate of magnesia had caused death, when given to a child in rather an unusual dose.

In the preceding experiments there is no necessity for any particular apparatus. For communicating heat, the spirit lamp alone should be used, and a substitute for this may be readily constructed by fitting a cork with a tin tube, about an inch long, loosely into the mouth of a wide-necked phial. The blow-pipe is employed by working jewellers and watchmakers, and therefore can be easily procured.

NITRIC ACID.

" *When concentrated,* nitric acid is easily known by the odour of its vapour, which is peculiar. When pure, the acid as well as its vapour is colourless; when mixed with nitrous acid, it is of various tints, and generally yellow or orange. The acid of commerce is at times rendered impure by sulphuric acid, a circumstance which must be attended to in applying the subsequent tests.—The simplest test for the nitric or nitrous acid is the action of copper, lead, or tin. If any of these metals in small fragments, or tin powder, be thrown into either acid, previously diluted with an equal volume of water, an effervescence takes place, which in the case of lead or copper is much accelerated by heat; nitric oxide gas is disengaged; and ruddy fumes of nitrous acid gas are formed when the gas comes in contact with the oxygen of the air. Another characteristic test, which has the advantage of being applicable on an extremely small scale, is morphia, the alkaloid of opium. This substance is turned in a few seconds to a beautiful orange-red colour by nitric acid, and after longer contact forms with it a bright yellow solution. No other acid has this effect. Muriatic acid does not act at all on morphia, and sulphuric acid chars and blackens it.—Many other characteristic tests might be mentioned for nitric acid; but those now specified are amply sufficient.

"*In a diluted state* this acid is not so easily recognized as the other mineral acids, for it does not form any insoluble salt or precipitate with bases.

"The process usually followed, consists in first ascertaining the acidity of the fluid, neutralizing with potass, evaporating to dryness, and ascertaining, by the addition of sulphuric acid and the application of heat, whether nitrous fumes are evolved. When the quantity of acid in the suspected fluid is sufficiently large, for example, about three grains, this process may be employed with advantage; by using a very small distilling apparatus, and operating cautiously, the leading properties of the disengaged acid may be determined; and, at all events, a sufficient quantity may be procured to try on it the test of morphia.—But when there is a probability that the quantity of acid is very small, a different plan must be followed. After neutralization and evaporation to dryness, the residue is to be put in a small tube, and heated for a second or two with a drop of sulphuric acid. A crystal of morphia is then to be dropped into the mass and moved round the edge of it, or in the moisture on the tube immediately above; upon which, if any nitric acid was originally present, the morphia will quickly acquire an orange colour.

"*Process for stains.*—Nitric acid produces on the skin a yellow stain, which gradually becomes dirty orange, and then, as the cuticle desquamates, of a dirty yellowish-brown; but in all of these states it is at once rendered for a time lively yellow in tint by the action of ammonia. I am not aware that any other yellow stain is similarly affected. Stains on cloth are generally yellowish, reddish-yellow, and brownish yellow, and are attended with more or less disintegration of the texture of the cloth. The method of analyzing all these taints is as follows:—The strained part is to be boiled in a few drachms of pure water several times in succession; and the liquid is then filtered, and may be subjected to litmus paper for the purpose of ascertaining its acidity. The absence of muriatic and sulphuric acids may next be proved on a drop or two contained in a small glass tube, by the non-action of nitrate of silver on the one hand, and nitrate of baryta on the other. It should be remembered at the same time, that, although the free acid be really the nitric, a scanty precipitate may be produced by one or both of these tests for the two other common mineral acids; because old clothes are frequently impregnated with particles of their salts, more especially with sulphates.—The mixture is then to be rendered neutral, or for the sake of greater facility, feebly alkaline, by adding a few drops of a diluted solution of caustic potass; after which the whole is evaporated to dryness, and in a vapour-bath, if practicable. The dry residuum is now to be put into a small short tube, heated with a drop or two of sulphuric acid, and brought in contact with a fragment of morphia, as recommended above in the process for the pure diluted acid. But if there is any reason to think that the quantity of acid is moderately large, it should be collected pure by a regular process of distillation.

"*Process for Mixtures.*—The detection of nitric acid in compound mixtures, such as the contents of the stomach, is seldom so easy a matter as its detection in stains; and indeed a sure and delicate process is still a desideratum in medico-legal chemistry.

"The first step is to try how far the organic matter may be sufficiently removed by a carefully conducted filtration as to admit of the nitre crystallizing. For this end, having constructed a loosely twisted cord of filtering paper, about eight inches long, and bent like a syphon,—place the shorter limb in the suspected mixture, which must be previously neutralized and diluted to the requisite extent, and place a proper vessel to receive the drops which fall from the other end of the syphon-filter. Then cover the whole apparatus with a jar to prevent evaporation. In the course of twenty-four or forty-eight hours the fluid will thus undergo a process of compound filtration, and will sometimes be so free from organic substances as to yield by evaporation crystals of nitre sufficiently pure to present the characteristic action on morphia when decomposed by sulphuric acid."—*Dr. Christison on Poisons.*

The use of Morphia as a test for nitric acid was first pointed out by myself in 1830, and has since been universally adopted by medico-legal authorities.—*W. B. O'S.*

MURIATIC ACID.

On the Muriatic or Hydro-chloric Acid, Dr. Christison remarks—

"Concentrated hydrochloric acid is at once known by its peculiar vapour or fumes, and still more delicately by the white fumes formed when its vapour comes in contact with ammoniacal gas. This test is applied by simply bringing near one another the open mouths of two bottles which contain the two substances. The yellow colour which it usually possesses is not essential.

"In its diluted state it is recognised with extreme delicacy by means of the nitrate of silver, which forms a dense white precipitate; a similar precipitate, however, is caused by the same test, with many other acids and their salts. The best method of determining the true nature of the precipitate for the purposes of medical jurisprudence, is to collect it on a filter, and then to dry it and heat it in a tube. It fuses under the point of redness, and unlike all the other white salts of silver, remains at a red heat undecomposed, and, on cooling, forms a translucent mass which cuts like horn.

"The effects of mixture on the tests for hydrochloric acid have not been particularly examined. On the whole, they will not prevent the tests being applied, but they will render the results doubtful, because very many organic substances, and particularly the mixture of food and secretions in the stomach, naturally contain the muriate of soda. Fortunately this is a matter of little consequence, for hydrochloric acid very rarely comes under the cognizance of the medical jurist as a poison."

These directions require but little comment. As far as the contents of the stomach are concerned, no chemical evidence can ever be of value, since not only the muriates but *the free acid* itself has been detected by Prout, Tiedemann, Gmelin, and others, in the secretions of that organ. The morbid appearances alone therefore, are to be taken into consideration. Neither is the evidence of *free* muriatic acid of any value, as regards vomited matters, in suspected cases, where recovery has taken place, and no morbid appearances can be observed, since in the acid eructations arising in dyspepsia and pyrosis, the muriatic acid has been recognized.

The case is, however, very different as far as regards a portion of liquid remaining in the unmixed condition. A portion of the acid should therefore be diluted, and to one part be added nitrate of silver, to a second nitrate of baryta: if a precipitate occurs in the former and not in the latter, the evidence of muriatic acid cannot be disputed, for reasons sufficiently apparent. The minute precipitate we have alluded to should be dissolved in a drop of caustic ammonia, and an *excess of pure* nitric acid added, when the chloride of silver will be again precipitated, an action which would not take place with any other ammoniacal solution of that substance.

I pass over the detection of Iodine, as it is almost impossible that this substance can for many years be the subject of criminal investigation in India. I now proceed to

OXALIC ACID.

This excellent article is quoted from Dr. Christison's essay with very slight alterations.

"Oxalic acid is commonly in small crystals of the form of flattened six-sided prisms, transparent, colourless, free of odour, very acid to the taste, and permanent in the air. Two other common vegetable acids, the citric and tartaric acids, differ from the oxalic in being seldom regularly crystallized, and never in fine prisms. In general appearance it closely resembles the sulphate of magnesia, for which it has been so often and so fatally mistaken. So close, indeed, is the resemblance, that repeatedly, on desiring several persons to point out which was the poison and which the laxative, I have found as many fix on the wrong as on the right parcel. The sulphate of magnesia has of course a very different taste, being strongly bitter. Various plans have been devised for preventing the accidents to which this unlucky resemblance has given rise. The best of them imply the use of a criterion or safeguard by the patient before he takes his laxative draught. It seems to have escaped the notice of those who have proposed the plans in question, that, if accidents are to be prevented in this manner, by far the simplest and most effectual security will be to let the public know that a laxative salt ought always to be tasted before it is swallowed. Its solubility has been much overrated by chemists. *Thenard* and others say it is soluble in twice its weight of temperate water; but it does not appear to me soluble in less then eleven parts.

"In determining the medico-legal tests for oxalic acid, it will be sufficient to consider it in two states,—dissolved in water, and mixed with the contents of the stomach and intestines or vomited matter. If the substance submitted to examination is in the solid state, the first step is to convert it into a solution.

"1. In the form of a pure solution, its nature may be satisfactorily determined by the following process :—

"The acidity of the fluid is first to be established by its effect on litmus paper.—A small portion is next to be tested with ammonia, which, if the solution of the acid be sufficiently concentrated, will produce a radiated crystallization, as the oxalate of ammonia formed is much less soluble than oxalic acid itself.—The remainder of the fluid is next to be subjected to the following re-agents. These might be applied at once. But it is better to neutralize the acid previously with any alkali; for then they act with greater delicacy. The remainder of the process consequently applies not only to oxalic acid itself, but also to all the soluble oxalates, which will presently be proved to be likewise active poisons.—The tests are the hydrochlorate of lime, sulphate of copper, and nitrate of silver.

"*Hydrochlorate of lime* causes a white precipitate, the oxalate of lime, which is dissolved on the addition of a drop or two of nitric acid,—and is not dissolved when similarly treated with hydrochloric acid, unless the acid is added in very large proportion.

"*Sulphate of copper* causes a faint bluish-white or greenish-white precipitate, which is not re-dissolved on the addition of a few drops of hydrochloric acid. The precipitate is the oxalate of copper. It is re-dissolved by a large proportion of hydrochloric acid.

"*Nitrate of silver* causes a dense, white precipitate, the oxalate of silver; which, when collected on a filter, dried, and heated, becomes brown on the edge, then fulminates faintly and is dispersed.

"2. Of the modifications in the analysis which are rendered necessary by the admixture of organic principles, none are of any consequence except those required in the case of an examination of the contents of the alimentary canal or vomited matters.

"Here a word or two must be premised on the changes which the poison may undergo in consequence of being mingled with other substances in the stomach or intestines. These may either be organic principles contained in the body, or substances introduced into the stomach as antidotes.

"As to animal principles, Dr. Coindet and I have proved, that oxalic acid has not any chemical action with any of the common animal principles except gelatin, which it rapidly dissolves; and that this solution is of a peculiar kind, not being accompanied with any decomposition either of the acid or of the gelatin. Consequently oxalic acid, so far as concerns the tissues of the stomach or its ordinary contents, is not altered in chemical form, and remains soluble in water.

"In such a solution, however, a variety of soluble principles are contained, which would cause abundant precipitates with two of the tests of the process,—sulphate of copper and nitrate of silver; so that the oxalates of these metals could not possibly be exhibited in their characteristic forms. The process for a pure solution, therefore, is inapplicable to the mixtures under consideration.

"But changes of still greater consequence are effected on the poison by exhibiting antidotes during life. It is now, I believe, generally known, since the researches of *Dr. Thomson*, and those of *Dr. Coindet* and myself, that the proper antidotes for oxalic acid are magnesia and chalk. Each of these forms an insoluble oxalate, so that if either had been given in sufficient quantity, no oxalic acid will remain in solution, and the proofs of the presence of the poison must be sought for in the solid contents of the stomach or solid matter vomited.

"The following process for detecting the poison will apply to all the alterations which it may thus have undergone:—

Process for compound mixtures.—If chalk or magnesia has not been given as an antidote, the suspected mixture is to be macerated if necessary for a few hours in a little distilled water, then filtered and the filtered fluid neutralized with carbonate of potash.—If, on the other hand chalk or magnesia has been given, the mixture is to be left at rest for some time, and the supernatant fluid then removed. This fluid, if not acid, may be thrown away; but if acid, it may be treated as already directed for a suspected mixture, where chalk or magnesia has not obtained entrance. After the removal of the supernatant liquid, pick out as many solid fragments of animal or vegetable matter as possible; and add as much pure water to the insoluble residue as will give the mass a sufficiently thin consistence. Add now to the mixture about a twentieth of its weight of carbonate of potash, and boil gently for two hours, or till the organic matter is all dissolved. While dissolution thus takes place, a double interchange is effected between the elements of the carbonate of potass on the one hand, and those of the earthy oxalate on the other, so that an oxalate of potash will at length exist in solution. The fluid when cold is next to be filtered, then rendered very faintly acidulous with nitric acid, then filtered and rendered very faintly alkaline with carbonate of potass, and filtered a third time. At each of these steps some animal matter will be thrown down.

"From this point onwards the process proceeds in the same way, whatever may have been the original form in which the acid existed in the mixture; for the oxalate of lime or magnesia in the second case is converted into oxalate of potash.

"Add now the solution of acetate of lead to the fluid as long as any precipitate is formed. Collect the precipitate on a filter, wash it well, and dry it by compression between folds of bibulous paper. Remove this precipitate, which consists of oxalate of lead and organic matter in union with oxide of lead, and rub it up very carefully while damp with a little water in a mortar. Transmit sulphuretted hydrogen gas briskly for an hour, so that the whole white precipitate shall be thoroughly blackened: filter and boil. In this manner is formed a sulphuret of lead, which retains a great deal of animal matter; and the oxalic acid, being set free, is found in the solution tolerably pure. Filtration before boiling is an essential point in this step, to prevent animal matter being dissolved by the water from the sulphuret of lead. More animal matter may still be separated by evaporating the liquid to dryness at 212°, keeping it at that temperature for a few minutes, and re-dissolving and filtering.—The solution will now exhibit the properties of oxalic acid.

In order to try the test of fulmination in such circumstances, it is essential to dry the precipitated oxalate of silver thoroughly before raising the temperature to the point at which fulmination usually occurs.

The discovery of oxalic acid in the form of oxalate of lime in the stomach or vomited matter is exposed to a singular fallacy, if a material quantity of rhubarb has been taken recently before death, or before the discharge of the vomited matter. For, according to the researches of *M. Henry* of Paris, rhubarb root always contains some oxalate of lime, and some samples yield so much as 30 and even 33 per cent."

THE ARSENICAL POISONS.

For details relative to these poisons, see " Arsenic" in the body of the work.

ANTIMONIAL POISONS.

The preparations of antimony which are most likely to engage the attention of the toxicological chemist, are the tartar emetic, the precipitated sulphurets, and the chloride, or butter of antimony. The physical properties of the two former require no notice; the last, it will be remembered, is prepared by boiling the sulphuret of antimony with muriatic acid, when sulphuretted hydrogen is expelled, and a chloride of antimony formed, which usually exists in the state of a gelatinous fluid, and which, when thrown into an alkaline solution, is decomposed, a white protoxide of antimony being thrown down. All the soluble preparations of antimony are decomposed by many organic substances, such as astringent vegetable infusions, &c.; they are also decomposed by sulphuretted hydrogen gas, an orange-red sulphuret of antimony being formed, which sulphuret, when treated with caustic potash, or subject to the action of hydrogen gas, forms either a sulphuret of potassium or of hydrogen, and metallic antimony is set free. Metallic antimony, again, is a bluish-grey metal, fixed in the fire, except when exposed at the same time to currents of gaseous matter; when heated in an open tube, it is oxidated with the production of a white shining vapour.

Such are the leading chemical features of antimony, a correct understanding of which is essential before the processes approved by Dr. Christison can be duly investigated.

Various authors have at different times recommended particular processes for the detection of this tribe of poisons; of these we may particularize that of Orfila, and the more recent one by Dr. Turner, which latter Dr. Christison recommends to be adopted. We quote the author's description. It is necessary also to extract his brief account of Orfila's method :—

" Professor Orfila recommends the following compound process. Either the antimony exists in solution, or it has been rendered insoluble by vegetable principles. The suspected matter being filtered, therefore, both the fluid and the matter remaining on the filter must be submitted to analysis. The fluid is to be treated with sulphuretted hydrogen, and the precipitate collected and reduced with potass in a crucible. The solid part is to be incinerated, and reduced also. In both cases globules of metallic antimony are procured if that metal was present in the mixture.

"This method is liable to some material objections. In the first place, if the fluid is alkaline, the sulphuretted hydrogen will not act; secondly, I have frequently found that the process of reduction does not answer on the small scale; and lastly, the double process may be dispensed with.

"A much better method of analysis is the following very simple and satisfactory process proposed by Dr. Turner. The subject of analysis is to be acidulated with a little muriatic and tartaric acids. The former will coagulate various animal principles which may be present. The latter Dr. Turner has found to possess the property of readily dissolving all precipitates whatsoever formed by reagents with tartar emetic, except that caused by sulphuretted hydrogen. Hence the addition of tartaric acid brings the whole of the antimony into the fluid, and consequently one-half of Orfila's process is dispensed with. The fluid so prepared is to be filtered, and a sulphuret formed and collected in the usual way. Dr. Turner found that the next step, the reduction of the sulphuret, cannot be effected on the small scale even in a crucible, much less of course in a tube; and on examining the flux, he discovered that a part of the sulphuret escapes decomposition, and that the metal which is reduced is too finely divided to be distinguishable. He was therefore led to propose the process of reduction by hydrogen which will develop antimony characteristically from only a tenth part of a grain of the sulphuret."

The experiment is performed by passing a current of hydrogen gas, generated in a double-necked bottle from diluted sulphuric acid, and iron filings or zinc. Dr. Christison describes it thus:—

"The best mode of shewing the presence of antimony in it, is the method of Dr. Turner, who proposes to place a little in a horizontal tube, to transmit hydrogen gas through the tube, and, when all the air of the apparatus is expelled, to apply heat to the sulphuret with a spirit-lamp. Sulphuretted hydrogen is evolved, and metallic antimony is left if the current of hydrogen is gentle, or it is sublimed if the current is rapid.

"If the stream of gas is slow, the metal remains where the sulphuret was; if the stream is rapid, it undergoes a spurious sublimation, and condenses on the tube either in detached crystals or in the form of a shining crust. When there is much animal or vegetable matter present in the sulphuret, the metal is not always distinctly visible. In that case Dr. Turner recommends that it be heated in an open tube, when it oxidates and sublimes in the form of a white powder, which glimmers, but is not crystalline and adamantine like the oxide of arsenic. A better method, however, is to dissolve the antimony by the action of nitric acid on the mixed material and broken fragments of the tube, and to throw down the orange sulphuret again from the neutralized solution by means of sulphuretted hydrogen."

From repeated examinations of Dr. Turner's process, we feel entitled to assert, that though theoretically perfect, it is practically unsuited to the purposes of medico-legal analysis. The objections we consider it exposed to, are, in the first place, the great difficulty to its performance by unpractised persons, who always constitute the majority of persons interested in these cases,—a difficulty which arises as well from the impossibility, in many instances, of obtaining tube apparatus of so complicated a kind, as, from the nicety of adjustment and manipulation, the experiment requires.

The truth, we believe, is, that both the authors have committed the error of doing a work of needless difficulty in seeking for the reduction of the metal at all, and that they might as well refuse to admit the recognition of the sulphate of baryta, unless they had previously obtained "barium," its metallic base. In the first place there is no metallic sulphuret whatever prepared by transmitting sulphuretted hydrogen through a solution, which even remotely resembles the rich red colour of the sulphuret of antimony; secondly, if further proof be required, just as conclusive evidence can be obtained from one-twentieth—nay, one-fiftieth part of a grain of this sulphuret, and with infinitely less trouble than is necessary for the reduction process. The annexed simple experiment will demonstrate the correctness of this assertion.

Having transmitted the sulphuretted hydrogen through the suspected liquid, prepared as Dr. Turner judiciously recommends, the liquid should be boiled, and allowed to cool and deposit the precipitate; the greater part of the supernatant fluid should then be removed with a suction tube, leaving as much as is sufficient to suspend the precipitate till it is decanted upon a watch crystal; it should then be washed with distilled water on the crystal, the fluid removed by the cautious use of a fine-drawn capillary tube, and it should next be placed near the fire-place till perfectly dry.

About ten drops of muriatic acid and five of nitric acid are next to be dropped over this precipitate, and the crystal being supported on a ring of copper-wire, the fluid is to be boiled over a small spirit lamp flame. In three or four minutes the red colour of the sulphuret disappears with effervescence, and an extremely small yellow globule of sulphur is seen swimming on the surface of the fluid, which should then be allowed to cool, and the little particle of sulphur removed with the point of the capillary tube. The fluid should now be evaporated to dryness, when a transparent gummy residuum, the chloride or butter of antimony, remains. If a few drops of distilled water be now dropped over this, an insoluble white powder, the protoxide of antimony, is immediately formed. The process of washing is to be repeated again, the white powder dried by a gentle warmth, and, finally, heated over the spirit lamp flame, when it changes to a beautiful golden yellow.

We have thus a chain of evidence simply and easily obtained, and withal indisputable in its kind. There is no sulphuret of the same red tint as that of antimony—there is no red sulphuret but that of antimony, which, decomposed by nitro-muriatic acid, will yield a residuum precipitable by water; and, thirdly, there is no powder but the protoxide of antimony, which, similarly obtained, becomes of a yellow colour when exposed to heat. The theory of the process is also readily understood. The process now proposed possesses, moreover, the advantage of extreme facility of execution; a watch-glass can be procured anywhere, and the whole investigation completed in half an hour, without the necessity of constructing the pretty, but complicated apparatus, represented in Dr. Turner's engraving. I am by no means inclined to question the necessity of obtaining the metallic base of poisonous preparations as a general rule. Antimony, however, constitutes the exception, as will be seen in the notices of lead, copper, silver, mercury, and arsenic. In this instance it is entirely unnecessary; and the attempt at the reduction of the metal will usually fail, and, moreover, prevent the application of much more certain experiments.

Finally, it is of essential importance to ascertain whether tartar emetic or antimonial powder has been administered before the death of the individual whose case is investigated. If it have, it is perfectly plain that no chemical evidence can be of any importance.

MERCURY AND ITS PREPARATIONS.

The extreme excellence of Dr. Christison's directions for the detection of the most important substance included in this class; viz. the corrosive sublimate, or bi-chloride of mercury, renders it almost unnecessary for me to offer any observations, in addition to the subjoined extracts, respecting this poison individually.

The general properties, whether physical, chemical, or medicinal, of the various mercurial preparations, are so well recognized by every intelligent practitioner, that it is entirely needless for me to dwell upon them here. Dr. Christison's treatise should indeed be consulted by every one who wishes to become minutely and intimately conversant with mercury and its compounds, for in no other work will there be found so masterly a description of its various preparations, as in the chemical division of the chapter in which he treats of this subject.

I proceed to quote his directions for the detection of the corrosive sublimate. It will be observed that they refer to this individual poison alone, and scarcely apply to any of the other soluble mercurial compounds.

"On the whole, the following plan has appeared to me the most simple and most generally applicable. It is a double process, of which sometimes the first part, sometimes the second, sometimes both, may be required. The first removes the corrosive sublimate undecomposed from the mixture, which may be accomplished when its proportion is not minute: the second, when the proportion of corrosive sublimate is too small to admit of being so removed, separates from the mixture metallic mercury; and the analyst will know which of the two to employ by using the proto-chloride of tin as a trial-test in the following manner: A fluid mixture being in the first instance made, if necessary, by dividing all soft solids into small fragments and boiling the mass in distilled water, a small portion is to be filtered for the trial. If the proto-chloride of tin causes a pretty deep ash-gray or grayish-black colour, the first process will probably be successful; if the shade acquired is not deep, that process may be neglected, and the second put in practice at once."

The proto-chloride of tin, it is here necessary to state, is prepared by boiling strong muriatic acid on tin powder, till the metal ceases to be dissolved; the liquid should then be carefully preserved in a closely stoppered bottle. It should be remembered that the analyst should always prepare this test himself, since it is seldom, we might almost say never, sold of the requisite degree of purity in the shops. Its mode of action with the solution of bi-chloride of mercury is simple; it proceeds from the strong attraction which the *proto*-chloride of tin manifests for additional quantities of chlorine, by virtue of which it first removes one atom of chlorine from the corrosive sublimate, reducing it to the condition of calomel, or the proto-chloride of mercury; and this it again deprives of its one remaining atom of chlorine, metallic mercury being precipitated in the form of a dark, minutely divided powder.

"*First Branch of the Process.*—In order to remove the corrosive sublimate undecomposed, the mixture, without filtration, is to be agitated for a few minutes with about a fourth part of its volume of sulphuric ether, which possesses the property of abstracting the salt from its aqueous solution. On remaining at rest for half a minute, or a little more, the etherial solution rises to the surface, and may then be removed. It is next to be filtered if requisite, evaporated to dryness, and the residue treated with boiling water, upon which a solution is procured that will present the properties formerly mentioned as belonging to corrosive sublimate in its dissolved state."

A long phial is the best instrument for the performance of this experiment, and in order to prevent the evaporation of the ether, the phial should be corked during the agitation. The removal may then be accomplished by a suction tube, (or if this cannot be obtained, by two or three quills connected together,) and the evaporation completed on a porcelain capsule, or a china saucer. The residuum should then be redissolved, and a drop or two placed on each of four watch crystals. A minute drop of a pure solution of the hydriodate of potash is to be applied to the first, when a precipitate takes place, usually yellow at first, and then becoming a carmine red; lime water is to be added to the second, when a brick-red precipitate, the hydrated red oxide of mercury, is thrown down. The third should be treated with ammonia, which causes a white precipitate, the triple proto-chloride of mercury and ammonia. Proto-chloride of tin is then to be added to the fourth, when a precipitate is deposited, at first white, and then becoming a dark-grey.

Finally, the fluid remaining in the capsule is to be agitated with the proto-chloride of tin, the precipitate dried, collected, and heated in a small glass-tube, when mercurial globules are immediately procured.

The preceding is an epitome of the observations of Dr. Christison in his notice of the properties of pure solutions of the corrosive sublimate, modified by ourselves as far as the manipulation is concerned. We now proceed to the second branch of Dr. Christison's process, the necessity for which we may state, briefly, to arise from the circumstance that corrosive sublimate is decomposed by many soft animal solids and solutions, by albumen, for example, the bi-chloride being reduced to the condition of calomel, which is no longer soluble in ether or water.

"*Second Branch of the Process.*—If the preceding method should fail, or shall have been judged inapplicable, the mixture is to be treated in the following manner:—In the first place, all particles of seeds, leaves, and other fibrous matter of a vegetable nature, are to be removed as carefully as possible. This being done, the mixture, without undergoing filtration, is to be treated with proto-chloride of tin, as long as any precipitate or coagulum is formed. This precipitate, even if it contains but a very minute proportion of mercury, will have a slate-grey tint; it is to be collected, washed, and drained on a filter, from which it is then to be removed without being dried, and care should be taken not to tear away with it any fibres of the paper, as these would obstruct the succeeding operations. The mercury exists in it in the metallic state for reasons formerly mentioned. The precipitate is next to be boiled in a moderately strong solution of caustic potass, contained in a glass flask, or, still better, in a smooth porcelain vessel glazed with porcelain; and the ebullition is to be continued till all the lumps disappear. The animal and vegetable matter will thus be dissolved; and on the solution being allowed to remain at rest, a heavy greyish-black powder will begin to fall down in a few seconds. This is chiefly metallic mercury, of which, indeed, globules may sometimes be discerned with the naked eye, or with a small magnifier. In order to separate it, leave the solution at rest under a temperature a little short of ebullition for fifteen or twenty minutes. Fill up the vessel gently with hot water without disturbing the precipitate, so that a fatty matter, which rises to the surface in the case of most animal mixtures, may be skimmed off first with a spoon, and afterwards with filtering paper; then withdraw the whole supernatant fluid, which is easily done on account of the great density of the black powder. Transfer the powder into a small glass tube, and wash it by the process of affusion and subsidence till the washings do not taste alkaline. Any fibrous matter which may have escaped notice at the commencement of the process, and any lumpy matter which may have escaped solution by the potass, should now be picked out. The black powder is the only part which should be preserved. If the quantity of powder is very minute, an interval of twelve hours should be allowed for each subsidence. Lastly, the powder is to be removed, heated, and sublimed, as in the last stage of the process already described for detecting corrosive sublimate in a pure solution. The second branch of this process is very delicate. I have detected by it a quarter of a grain of corrosive sublimate mixed with two ounces of meat, or with five ounces of new milk, or porter, or tea made with a liberal allowance of cream and sugar. I have also detected a tenth part of a grain in four ounces of the last mixture, that is, in 19,200 times its weight."

It cannot, however, be denied, that though individually perfect, as far as corrosive sublimate is concerned, still the preceding method is exposed to some collateral objections. Thus, the ether acts on corrosive sublimate alone; and the proto-chloride of tin, though it does affect other mercurial salts to a certain extent, yet does not operate with either delicacy or certainty with any but the muriatic preparations; thus, there are some insoluble compounds, such as the subsulphate, dipernitrate, and the red precipitate, which the proto-chloride of tin scarcely acts upon at all.

In a case of this description, Dr. Christison's process may be applied to a mixture containing an abundance of mercury, and yet give no adequate indication of its presence. The observation applies particularly to the yellow subsulphate or turpeth mineral, which has been used to our own knowledge as a poison in England, especially for the malicious destruction of cattle.

DEVERGIE'S COMPREHENSIVE METHOD.

"Treat the mixture supposed to contain mercury with diluted hydro-chloric acid till all the solid matter is dissolved. Evaporate, in order to expel the greater part of the acid employed. Add water to the remainder, and transmit chlorine to coagulate and remove the animal matter. Filter, boil, and concentrate; then immerse for ten minutes a small plate of pure tin, which, if mercury is present, will immediately be whitened; immerse another plate of tin for ten minutes; and continue this part of the process till the plates cease to be whitened. Dry the tarnished plates, scrape off the tarnished surfaces, put the scrapings in a proper tube, and heat it over a spirit-lamp; the mercury will be driven off from the amalgam and condense in a ring of globules. By this plan Devergie says, he detected a quarter of a grain of corrosive sublimate in four ounces of blood, nay a sixteenth and even a thirty-second part of a grain in eight ounces. I have repeated it, and found it in most circumstances convenient and accurate; but doubts may be entertained whether it is universal in its application."

Under these circumstances I have been induced to seek a process by which this object may be fulfilled, and I can recommend the following with some confidence as to its delicacy and precision, premising that it is by no means offered as an improvement on the process extracted from Dr. Christison's treatise, as far as corrosive sublimate alone is concerned. Its object is to supply the desideratum,—a method by which any mercurial may be detected. Neither is our proposition strictly original, as it is founded both on Orfila's and Devergie's suggestions, and also includes a part of a process suggested by Mr. Sylvester some time since.

In the first place, we would recommend that Dr. Christison's process should be always performed on small portions of the suspected mixture, as by this mode the corrosive sublimate may at once be detected.

Should no indications of mercury be afforded by the ether and the proto-chloride of tin, we would then direct that the mixture be filtered through coarse paper, that the fluid part be concentrated by evaporation, having been previously acidulated with nitric acid; when sufficiently concentrated, it should be reserved for a further examination.

The solid part may contain the subsulphate of mercury, or turpeth mineral, the subnitrate, the red precipitate, the acetate, or cyanuret in a state of admixture with organic matter; from all these the mercury may be separated in the condition of an oxide by ebullition with caustic potassa for about an hour; the protoxide, however, as Dr. Christison justly remarks, may be either mechanically suspended or chemically dissolved in the alkaline solution. To obviate this, we add, after the boiling with potash, a large excess of nitric acid, which, in complicated mixtures, usually produces an abundant precipitate of caseoùs and albuminous matter; the mixture is then digested by a gentle heat in a Florence flask for at least six hours, by which time all the oxide of mercury has united with the nitric acid, and remains in solution in the state of the mixed proto-nitrate and pernitrate of mercury.

Filtration should now be performed, the filtered fluid concentrated by evaporation, and mixed with the fluid first prepared. It should then be allowed to cool, and again filtered should any further organic deposition have occurred.

The last step of the process may now be proceeded with; it consists in introducing a thin slip of gold, bound round with a coil of iron wire. The slip of gold is further to be treated in precisely the manner recommended by Devergie for the tin.

The advantages of the process above detailed over the others are briefly these:—It is more general than Dr. Christison's, embracing the subnitrates, subsulphates, acetates, and the red precipitate. Secondly, it is free from the objection advanced by Dr. Christison against Orfila's process, inasmuch as the object is not to *collect* the protoxide, but to prepare it for the action of the nitric acid. Thirdly, it ensures the solution of every solid compound formed by the salts of mercury with organic matter, whether from the animal or *vegetable* kingdom. Fourthly, it is of the utmost facility of execution. Finally, it is almost infinitely delicate in its indications. We have detected by its means the thirtieth part of a grain of *calomel* (the most difficult of all the preparations) in a ℥xij mixture composed of ℥x of strong tea and ℥ij of blood.

The chemical treatment of poisoning by mercury, varies according to the preparation employed. If the corrosive sublimate, liquid albumen (the white of eggs) affords a certain antidote by reducing this salt to the condition of calomel. If the nitrate be the poison, a mixture of the muriate of soda and carbonate of ammonia may be advantageously given, and the stomach-pump should be applied.

There still remains one important point connected with the chemical inquiries in any medico-legal investigation in which mercury is concerned, to which we must briefly advert. Except the case in which corrosive sublimate is at once removed by ether, the chemical analysis directed for organic mixtures always gives the same indications, as would be the case had calomel been *medicinally* taken a short time before death. This is a circumstance of moment, and one of which a crafty villain might avail himself in his atrocious purposes in a manner which the public safety does not permit us to describe. We have, however to repeat here, the remark we once before advanced, that we speak but of the chemical evidence, and do not take into account the collateral circumstance by which information can be obtained.

LEAD POISONS.

Dr. Christison subdivides the chemical part of his excellent article on lead into two sections, one referring to its detection after it has been administered in large quantities; the second to its relations to medical police, comprehending the mode in which it is affected by water—its use in several arts—the adulteration of various articles of food to which it is applied. To the first section we must limit ourselves exclusively.

The author, following his accustomed arrangement, first describes the metal, and such of its compounds as come within the province of judicial research. Of these he enumerates litharge, or the semi-vitrified protoxide, minium, or the red oxide, and the acetate, or sugar, of lead. All these, he correctly states, agree in the property of being blackened by sulphuretted hydrogen gas. The acetate is soluble in water, the litharge and carbonate in nitric acid, and the red oxide but partially soluble in that menstruum. Carbonate of lead also, when heated to redness, assumes as it cools a yellow colour, the carbonic acid being expelled, and the yellow protoxide remaining behind. The solutions of lead are extremely liable to decomposition by animal or vegetable matters, many vegetable infusions, and almost all animal solutions precipitating the oxide of lead in combination with organic matter.

We pass over the enumeration of the tests which the author recommends for detecting lead in pure solution, reserving our observations on them till we notice his mode of proceeding with complicated mixtures.

"The process which has appeared to me the most convenient is a modification of the former one. In the first place, a little nitric acid should be added to the suspected matter before filtration; for nitric acid I find redissolves any insoluble compound formed by the salts of lead with albumen and other animal principles, as well as some of those formed with vegetable principles; and consequently renders it more probable that the poison will be detected in the first part of the analysis, if present at all.[*] This being done, sulphuretted hydrogen gas is to be transmitted through the fluid part of the mixture; and if a dark-coloured precipitate is formed, the whole is to be boiled and filtered to collect the precipitate."—pp. 408, 409.

Several other black precipitates are thrown down, however from metallic solutions by this re-agent, viz., from the soluble salts of mercury, silver, copper, bismuth, &c. A mode of discrimination, therefore, becomes essentially necessary, and the author proceeds in the following manner :—

"In order to ascertain that the precipitate positively contains lead, I should advise a different process from that recommended by Orfila, which I have found to give, on a small scale, metallic particles of too small a size and indistinct an appearance. Those who are accustomed to use the blowpipe may put the sulphuret into a little hole in a bit of charcoal, and reduce it by the fine point of a blow-pipe flame when a single globule is procured, which is easily distinguished by its lustre and softness. A much better process, for those who are not accustomed to use the blow-pipe, and, perhaps a better test of the existence of lead in all circumstances, is to heat the sulphuret to redness in a tube, and to treat it with strong nitric acid, without heat or with the aid of a gentle heat only. The lead is thus dissolved without the sulphur being acted on. The solution is then diluted with water, filtered, evaporated to dryness, and gently heated to expel the excess of nitric acid. If the residue be dissolved in water, it will present the usual characters of a lead solution when subjected to the proper liquid tests. Of these the hydriodate of potass is to be preferred when the quantity is too small for trying more of them. But for this purpose great care must be taken to expel all the excess of nitric

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[*] The precipitate formed by acetate of lead with albumen is dissolved by nitric acid. From that formed with milk the acid removes the oxide of lead entirely, leaving the casein.

acid, because an excess will strike a yellow colour with the test, though lead be not present.

"If the preceding process should not detect lead in the filtered part of the mixed fluid, then the insoluble matter left on the filter is to be incinerated, as Orfila suggests. This branch, however, will be very rarely required, if lead be present, because the precaution of adding nitric acid previous to filtration dissolves the lead from most of its compounds which are insoluble in water. The process of incineration in medico-legal analysis generally should be avoided if possible, as it is not easily managed by unpractised persons."—pp. 409, 410.

It appears above, that Dr. Christison does not consider the reduction of the metal essential, and that he considers the effect of certain re-agents as sufficiently characteristic; these he has described at p. 382. The best, he states, are the chromate of potass, hydriodate of soda or potass, and metallic zinc; the first two cause lively yellow precipitates, the third produces the deposition of the metallic lead in an arborescent crystallization. To the two former of these tests, individually considered, some objections apply, none of which have escaped the author's notice. Still the special attention which the strictness of these investigations demands, requires fuller remarks. Thus the sulphate of copper is precipitated black by sulphuretted hydrogen; this black precipitate is dissolved by nitric acid, and when evaporated to dryness and again redissolved, will strike a yellow colour with hydriodate of potassa, unless, all excess of acid be expelled, which, in unpractised hands, will not usually happen, the evaporation being usually concluded when brought to dryness; whereas, from the tendency of nitric acid to form bi or super-salts, a bi-nitrate of copper is usually produced, the excess of acid in which acts on the hydriodate in the described manner. We may add also, that from the scandalous adulteration of the hydriodate of potash of commerce, the evidence of the whole experiment may be destroyed at this stage of the inquiry, carbonates, chlorides, &c., being precipitated, and obscuring the colour of the hydriodic acid. In minute quantities, finally, the action of metallic zinc will not assist us, for it is scarcely entitled to the epithet "delicate," applied to it by the author.

It is thus evident that in small quantity, and under the management of an inexperienced person, the several tests may have been applied to a copper solution, and positive testimony given to the detection of lead. We are, therefore, inclined to prefer the reduction process as performed on charcoal with the blow-pipe flame, an operation which is extremely easy, and affords at once the most striking and satisfactory evidence which can be obtained. Minute instructions will not, however, be misplaced, and we would recommend the operator to practise the experiment on sulphuret of lead, before he proceeds to the examination of the suspected substance.

A small hollow should be scraped in a piece of dense fine charcoal, and in this the sulphuret should be placed, moistened with a drop of distilled water, in order to make it adhere to the support; it should then be touched with the *interior* or blue flame of the blow-pipe, when the reduction almost instantly takes place. The little globule of metal should then be removed and examined, for we have now to distinguish it from silver, which, take it in the pure state, is a white, shining, and soft metal; the globule should, therefore, be flattened by gentle pressure, replaced on the charcoal, and touched with the *furthest* point of the flame, when it quickly disappears, and on withdrawing the charcoal, two bright concentric circles of red and yellow remain, being the yellow and red oxide of lead. Nothing can be so conclusive as this experiment, and its success is perfectly certain.

When a soluble salt of lead is taken to an excessive dose, the phosphate of soda, or sulphate of soda or magnesia, should be administered as soon as possible, and vomiting speedily excited; an insoluble sulphate or phosphate is thus produced, and an effectual antidote supplied. A point now remains for consideration, which Dr. Christison has omitted in his work, viz. the means of detecting lead in the condition of the extremely insoluble phosphate or sulphate contained in the vomited matters; for this purpose the matters should be agitated with a considerable quantity of water; though mixed with solid matter, the phosphate or sulphate from its weight quickly subsides, and should be collected, washed, and heated to redness with charcoal in a glass-tube; phosphuret, or sulphuret of lead is thus generated, either of which may be reduced by the blow-pipe in the manner above directed; the reduction should be accomplished in the interior flame, when, if the salt be the phosphate, which the analyst should always inquire, the process presents a modification thus described by Griffin, in his excellent manual on the use of the Blow-pipe, p. 177, and for the accuracy of which description we can vouch from repeated trials.

"Before the blow-pipe alone on charcoal, in the *exterior* flame, it melts, and on cooling forms a dark-coloured polyhedral crystal, the faces of which present concentric polygons. In the interior flame it exhales the vapour of lead; the flame assumes a bluish colour, and the globule on cooling forms crystals with, broad facets inclining to pearly whiteness. At the moment it crystallizes a gleam of ignition may be seen in the globule. If the crystallized mass be pulverized and heated with borax, there results in the first place a milk-white opaque enamel: upon the continuance of the heat this effervesces, and at length becomes perfectly transparent, the lower part of it being studded with metallic lead."

"Another and still easier mode is, to suspend the phosphate or sulphate in water, transmit sulphuretted hydrogen, wash and reduce by the blow-pipe flame. In both cases the concentric circles of red and yellow oxide remain on the charcoal when the flame is removed."

The foregoing extracts and remarks are amply sufficient for the guidance of the examiner of matters of food, drink, &c., suspected to be adulterated with lead, with the exception of cheese, which has been and is, occasionally, coloured with red lead. In this case the cheese should be chopped into fragments and suspended in water, when, if blackened by sulphuretted hydrogen, the indication may be considered decisive without further trouble.

COPPER POISONS.

The detection of these poisons is exposed to a singular fallacy, arising from the presence of traces of copper in almost all animal and vegetable substances.

The existence of the oxide of copper in organic matters was first noticed and demonstrated by the celebrated Assessor Gahn, of Fahlun, who was accustomed to exhibit the production of distinct particles of metallic copper reduced by him with the mouth-blow-pipe from a quarter of a sheet of burnt paper. Singular as was this fact, it seems to have for some time attracted but little attention. The next experiment worthy of record on the subject, is stated by *Bucholz*, who detected copper in the ashes of the *amomum zedoaria*, in the galanga root, in others of the same family, and in various other vegetables of distinct kinds. These researches were pursued by *Meisner* with further success; and lastly, *M. Sarzeau* has shewn in the *Annales de Chimie* for July, 1830, that not only does copper exist in the plants enumerated by Meisner, but in various products of the animal department of organization. I should also say, that in the highly useful translation of Rose's Manual of Analysis, it is stated, that copper may be detected in solutions of sugar by a reagent to which I shall presently have occasion to revert.

Of these experiments, those of M. Sarzeau are, in a medico-legal point of view, by far the most important. He enumerates cinchona bark, two kinds of coffee, cheese, and blood, as substances in which he has detected minute quantities of the metal; and in coffee, he states it to exist to the extent of a grain in the pound. The process by which M. Sarzeau proceeded, was by drying and incinerating the substances for examination, treating the ashes with dilute nitric acid, saturating the solution with ammonia, which throws down several foreign matters, still retaining the copper in solution. The mixture is then slighty acidulated with acetic acid, and the few drops of ferro-cyanate of potash added. The first effect occasioned is the production of a brownish tinge, which deepens in some hours, and in the course of twenty-four hours (in some cases longer), a brown floculent precipitate is deposited, the ferro-cyanate of the oxide of copper.

To obtain the metal from this precipitate is exceedingly easy. It consists in heating the precipitate to dryness on a porcelain capsule, by which the hydrocyanic acid is partly expelled, and partly retained in combination with the oxide of iron, leaving on the capsule a mixture of the peroxide of copper, and prussian blue; on this you act with a little dilute sulphuric acid, which dissolves both metals, and by the addition of ammonia the iron is precipitated, and the copper retained in solution as before. You have now but to filter, acidulate with a little sulphuric acid, and introduce a bit of pure iron wire, which shortly becomes coated with metallic copper.

Since the publication of M. Sarzeau's paper, I have repeated the process with every precaution against fallacy I could devise, being impressed with the idea that if I obtained similar results, they should induce medical jurists to be cautious in deciding on poisoning or adulteration by copper on chemical evidence alone. My experiments fully confirmed all M. Sarzeau's statements.

Concerning the source of the copper thus detected, I shall not at present enter into any speculations, further than to remark, that with respect to bread, some difference of opinion may arise whether the copper actually exists in the corn, or is accidentally or designedly introduced during the subsequent steps of the preparation of bread. In support of the natural existence of the copper in corn, we have, first, the analogy of its undeniable existence in other vegetables; secondly, the evidence of M. Lefebure, a Dutch chemist of high reputation, who declares that he has found it in corn; and, thirdly I may add my own experiments on bread, in which no adulteration of this kind has, in England, been suspected. In opposition to these opinions, and in proof of the designed adulteration, I may adduce the recent conviction and confessions of several bakers in Belgium, for practising this adulteration; secondly, in my own experiments, I have never succeeded in tracing copper in corn itself, although I have operated on a specimen growing over an extensive stratum of copper ore. That the copper may occur in bread accidentally, I conceive may arise from the *detritus* of millstones, which, in some districts, are, I am told, incorporated with malachite or the carbonate of copper; and lastly, from the evidence of *M. Lodibert*, who in a debate on this subject at the *Académie Royal de Médecine, séance de Janvier*, 1830, stated that the sulphate of copper was used for the prevention of the malting of grain. My own impressions on the subject are, that copper usually finds its way into bread by accident. The Belgic bakers used it by mistake for blue alum. However, my experiments as yet have been too limited to enable me to pronounce a positive opinion on the subject.

However this question be decided, it is manifest that the natural existence of copper in the other substances I have described, must exercise an important influence over medico-legal analysis, and oblige us in all inquiries not only to detect the metal, but to ascertain the quantity present.

The points to be attended to in the quantitative detection of copper are fourfold. 1st, To bring all the copper in the suspected mixture into a state of solution. 2ndly, To free that solution from organic matter as much as possible. 3rdly, To throw down from the solution an insoluble compound of copper, the combining proportions of which are well known; and *lastly*, to reduce that insoluble compound to the metallic state.

The *first* of these objects, namely, the dissolving of the copper, is readily and certainly effected by boiling the suspected material in dilute nitric acid for an hour in a porcelain vessel glazed with porcelain.

The *second* point, viz., the freeing the solution from organic matter, is best obtained after the necessary mechanical filtration by the addition of caustic ammonia, which throws down caseum, albumen, the oxide of iron (which is often present,) and various earthy matters, such as the phosphate of lime, while it retains the oxide of copper in solution.

The *third* step consists in the transmission of sulphuretted hydrogen through the mixture previously acidulated with acetic acid. An insoluble *sulphuret of copper* is formed, which readily subsides after boiling, and may be collected on a small filter. However, as the sulphuret of copper thus obtained is always associated with organic matters, it should be incinerated on a little porcelain capsule over the spirit-lamp flame, and the residue redissolved in dilute sulphuric acid. This fluid is again to be neutralised with ammonia, a little acetic acid added, and sulphuretted hydrogen again transmitted. The sulphuret is now quite pure. It should then be washed, removed, dried in a water-bath, and carefully weighed. Of this black sulphuret—

100 parts correspond to 61 metal.—

Grs.	to	80 peroxide.
1 Grain........	2	anhyd. sulph. of copper,
....	3⅛	crystallized ditto,
....	1⅝	neut. anhyd. per acetate,
....	2¼	crystallized ditto,
....	1¼	anhyd. carbonate of copper,
....	1½	crystallized.

Lastly, this sulphuret should be reduced to the metallic state by boiling it with a little dilute nitric acid in a test tube, neutralising with ammonia, which strikes a beautiful blue colour, re-acidulating with sulphuric acid, and introducing pure iron wire.

The reasons why I prefer this process to that of incineration and precipitation by the ferro-cyanate of potash, are briefly,* because the sulphuretted hydrogen does not indicate copper in the substances in which that metal naturally exists; and, secondly, because the combining proportions of the ferro-cyanate of copper have not yet been ascertained with sufficient precision.

Before I conclude, there is one point which I would remind the student is of vital importance to be attended to in our inquiries on any fatal case of poisoning by this metal; it is, whether a cupreous emetic has not been administered before death, and if it has been, what was the precise quantity of the dose? It is obvious, that a professional poisoner might endeavour to protect himself from suspicion and conviction by the open administration of a copper emetic, under the pretence of ridding the stomach of any deleterious and unknown substance. In such a case it is evident, that if to our question as to the quantity of copper contained in the emetic, he replies, five grains, and that on analysis we find sulphuret of copper equivalent to twelve grains, that the chemical evidence is as conclusive as if seven grains had been detected where no emetic had been given.

DETECTION OF ZINC.

I quote Dr. Christison's observations on this head without comment:—

"The compounds of *zinc*, which have been long used in considerable doses in medicine, have sometimes occasioned serious and even fatal effects. Partly on this account, and partly because one of them, the sulphate of zinc, being the emetic most commonly used in the treatment of poisoning, is apt to complicate various medico-legal analysis, it will be proper to notice both its physiological properties, and the mode of detecting it by chemical means.

"The only important compound of this metal is the sulphate or *white vitriol.* As usually sold in the shops, it forms small, prismatic crystals, transparent, colourless, of a very styptic metallic taste, and exceedingly soluble in water.* That which is kept by the apothecary is tolerably pure; but the ordinary salt of commerce commonly contains an admixture of sulphate of iron, by the presence of which the natural action of the tests for zinc is materially modified.

" The solution of the pure salt is precipitated white by the *caustic alkalis,* an oxide being thrown down, which is soluble in an excess of ammonia. The *alkaline carbonates* also precipitate it white, the carbonate of ammonia being the most delicate of these re-agents. The precipitate is soluble in an excess of carbonate of ammonia, and is not thrown down again by boiling. The precipitate produced both by the alkalies and by their carbonates becomes yellow, when heated nearly to redness; and on cooling it becomes again white. This is a characteristic property, by which the oxide of zinc may be known from most white powders. It has been already observed, however, that the oxide of antimony is similarly affected (446). The *ferro-cyanate of potass* also causes a white precipitate. A stream of *sulphuretted-hydrogen* likewise causes a white precipitate, the sulphuret of zinc, the colour of which distinguishes the present genus of poisons from all those previously mentioned, as well as from the poisons of lead. The precipitate is apt to be suspended till the excess of gas is expelled by ebullition. The action of this test will not distinguish sulphate of zinc from the salts of the peroxide of iron, by which white sulphur is disengaged from the gas in consequence of the peroxide of iron being reduced to the state of protoxide. The same decomposition takes place wherever there is free chlorine, as in many impure samples of muriatic acid.

" When the sulphate of zinc has been mixed with vegetable and animal substances, the action of the tests mentioned above is modified. In such circumstances I have found the following process convenient.

"The mixture being strained through gauze, it is to be acidulated with acetic acid, and filtered through paper. The acetic acid dissolves any oxide of zinc that may have been thrown down in union with animal matter. The filtered fluid is then to be evaporated to a convenient extent, and treated when cool with sulphuretted hydrogen gas,—upon which a greyish or white milkiness or precipitate will be formed. The excess of gas must now be expelled by boiling, and the precipitate washed by the process of subsidence and affusion, and collected on a filter. It is then to be dried and heated to redness in a tube. When it has cooled, it is to be acted on by strong nitric acid, which dissolves the zinc and leaves the sulphur. The nitrous solution should next be diluted, and neutralized with carbonate of ammonia; after which the liquid tests formerly mentioned will act characteristically. The effect of carbonate of ammonia, and that of heat on the carbonate of zinc which is thrown down, ought to be particularly relied on."

DETECTION OF OPIUM.

It is necessary to remind the student that opium is a vegetable exudation composed of various proximate principles; viz., morphia, meconic acid, narcotine, resin, caoutchouc, lignin, &c. Of these the two first are alone important, as far as the process for the detection of opium is concerned. They co-exist in opium in the state of the meconate of morphia, and from its watery infusion the first may be precipitated by ammonia, and the second by the acetate of lead, the meconate of lead being thrown down, which, when decomposed by sulphuretted hydrogen, sets free the meconic acid:—

"*Of the tests for Meconic Acid.*—Meconic Acid, as procured by evaporation, is in little scales of a pale-brown or yellowish tint, being rendered so by adhering resin or extractive matter, from which it has hitherto been found impossible to free it altogether. 1. When heated in a tube, it is partly decomposed and partly sublimed, and the sublimate condenses in filamentous radiated crystals. 2. When dissolved even in a very large quantity of water, the solution acquires an intense cherry-red colour, with the permuriate of iron; the sublimed crystals have the same property: only one other acid is so affected, namely, the sulpho-cyanic, a very rare substance. 3. Its solution gives a pale-green precipitate with the sulphate of copper, and, if the precipitate is not too abundant, it is dissolved by boiling, but re-appears on cooling.

"*Of the Tests for Morphia.*—Morphia, when pure, is in small beautiful, white crystals. Various forms have been ascribed to them; but in the numerous crystallizations I have made, it has always assumed the form of a flattened hexangular prism. It has a bitter taste, but no smell. A gentle heat melts it, and if the fluid mass is then allowed to cool, a crystalline radiated substance is formed. A stronger heat reddens and then chars the fused mass, white fumes of a peculiar odour are disengaged, and at last the mass kindles and burns brightly. Morphia is very little soluble in water. It is more soluble in ether. But its proper solvents are alcohol, or the diluted acids, mineral as well as vegetable. Its alcoholic solution is intensely bitter, and has an alkaline re-action. From its solutions in the acids, crystallizable salts may be procured, and morphia may be separated by the superior affinity of any of the inorganic alkalies, more particularly by ammonia. Morphia becomes instantly orange-red when treated with nitric acid. When suspended in water, and then treated with a drop or two of the permuriate of iron, it is dissolved, and forms a dirty indigo-blue solution. A concentrated solution in acetic acid is similarly acted on."

"*Of the process for detectiny Opium in mixed fluids and solids.*—Having stated these particulars of the chemical history of opium and its chief component ingredients, I shall now describe what has appeared to me the most delicate and satisfactory method of detecting it in a mixed state. 1. If there is any solid matter it is to be cut into small fragments, water is to be added if necessary, then a little acetic acid sufficient to render the mixture acidulous, and when the whole mass has been well stirred, and has stood a few minutes, it is to be filtered and evaporated at a temperature somewhat below ebullition to the consistence of a moderately thick syrup. To this extract strong alcohol is to be gradually added, care being taken to break down any coagulum which may be formed; and after ebullition and cooling, the alcoholic solution is to be filtered. The solution must then be evaporated to the consistence of a thin syrup, and the residue dissolved in distilled water, and filtered anew. 2. Add now the solution of subacetate of lead as long as it causes precipitation, filter and wash. The filtered fluid contains the morphia, and the precipitate on the filter contains meconic acid united with the oxide of lead. 3. The fluid part is to be treated with sulphuretted hydrogen to throw down any lead which may remain in solution. It is then to be filtered while *cold*, and evaporated sufficiently in a vapour-bath. If, notwithstanding the action of the salt of lead and that of the sulphuretted-hydrogen, the liquid is considerably coloured, the colour must be destroyed by filtering it through animal charcoal. The solution thus eventually procured is to be subjected to the tests for morphia formerly mentioned; and when the quantity is very small, the tests which ought to be chosen are—the taste, the action of per-chloride of iron on the fluid, and the action of nitric acid on the residue of its evaporation. 4. It is useful, however, to separate the meconic acid also; because, as its properties are more delicate, I have repeatedly been able to detect it satisfactorily, when I did not feel satisfied with the result of the search for morphia. Dr. Ure made the same remark in his evidence on the trial of Stewart and his wife. He detected the meconic acid, but could not separate the morphia. Suspend, therefore, in a little water the precipitate caused by the subacetate of lead;

transmit sulphuretted hydrogen till the whole precipitate is blackened; filter immediately without boiling; then boil, and if necessary filter a second time. A great deal of the impurities thrown down by the subacetate of lead will be separated with the sulphuret of lead, and the meconic acid is dissolved. But it requires in general farther purification, which is best attained by again throwing it down with subacetate of lead, and repeating the steps of the present paragraph. The fluid is now to be concentrated by evaporation, and subjected to the tests for meconic acid, more particularly to the action of perchloride of iron, when the quantity is small. If there is evidently a considerable quantity of acid, a portion should be evaporated till it yields crystalline scales, which have always a yellowish tint; and these are to be heated in a tube to procure the arborescent crystalline sublimate formerly described. About a sixth of a grain of meconic acid however, is required to try the latter test conveniently."

DETECTION OF NUX-VOMICA AND STRYCHNINE.

For this, Dr. Christison recommends the following process:—

"*Tests of Nux-Vomica.*—Nux-vomica, the most common of the species, is a flat, roundish kernel, hardly an inch in diameter, of a yellowish or greenish-brown colour, and covered with short silky hairs. In powder it has a dirty greenish-gray colour, an intensely bitter taste, and an odour like powder of liquorice. It inflames on burning charcoal, and when treated with nitric acid acquires an orange-red colour, which is destroyed by the addition of proto-chloride of tin. Its infusion also is turned orange-red by nitric acid, and precipitates grayish-white with tincture of galls. *Orfila* and *Barruel* have made some experiments on the mode of detecting it in the stomach, and the following is the plan recommended by them:—The contents of the stomach, or the powder, if it can be separated, must be boiled in water acidulated with sulphuric acid. The liquid after filtration is neutralized with carbonate of lime, and then evaporated to dryness. The dry mass is then acted on with successive portions of alcohol, and evaporated to the consistence of a thin syrup. The product has an intensely bitter taste, precipitates with ammonia, becomes deep orange-red with nitric acid, and will sometimes deposit crystals of strychnia on standing two or three days. These experiments it is important to remember, because, contrary to what take place in regard to the vegetable poisons generally, nux-vomica is very often found in the stomachs of those poisoned with it."

The same process applies to the bark of the nux-vomica, which also contains

BRUCINE.

This is detected by the violet stain given on the addition of the proto-chloride of tin to the crystalline residue of the alcoholic washings of the experiments described under the head of nux-vomica.

HYDRO-CYANIC OR PRUSSIC ACID.

For the chemical relations of this substance the student is referred to the body of the work.

CHEMICAL TREATMENT OF POISONING-ANTIDOTES.

In the preceding papers I have occasionally noticed the influence of chemical antidotes over the operations of some particular poisons, but I did so rather with reference to the alterations consequently required in the mode of analysis than with respect to the therapeutic powers of the antidote in question. I now proceed to enumerate *seriatim* the few effectual antidotes with which chemistry has supplied the practical physician.

To the general principles which regulate the operations of the chemical counter-poisons, Dr. Christison alludes in these terms :—

" In the instance of internal poisoning, the great object of the physician is to administer an antidote or counter-poison. These antidotes are of two kinds. One kind takes away the deleterious qualities of the poison, before it comes within its sphere of action, by altering its chemical nature ; the other controls its poisonous action after it has begun, by exciting a contrary action in the system. In the early ages of medicine almost all antidotes were believed to be of the latter description, but in fact very few such antidotes are known.

" The chemical antidotes act in several ways, according to the mode of action of the poison for which they are given. If the poison is a pure corrosive, such as a mineral acid, it will be sufficient that the antidote destroy its corrosive quality : thus the addition of an alkali or earth will neutralize sulphuric acid, and destroy, or at least prodigiously lessen, its poisonous properties. In applying this rule, care must be taken to choose an antidote which is either inert, or, if poisonous, is like the poison for which it is given, a pure corrosive or local irritant, and one whose properties are reciprocally neutralized. If the poison, on the other hand, besides possessing a local action, likewise acts remotely by an impression on the inner coat of the vessels, mere neutralization of its chemical properties is not sufficient ; for we have seen above that such poisons act throughout all their chemical combinations which are soluble. Here, therefore, it is necessary that the chemical antidote render the poison insoluble or nearly so, and that not only in water, but likewise in the animal fluids, more particularly the juices of the stomach. The same quality is desirable even in the antidotes for the pure corrosives ; for it often happens that in their soluble combinations these substances retain some irritating, though not any corrosive power. When we try by the foregoing criterions many of the antidotes which have been proposed for various poisons, they will be found defective, as precise experiments have in recent times actually proved them to be."

The first group of poisons for which an antidote is required, is that of—

THE MINERAL ACIDS.

Of these Dr. Christison speaks as follows :

" Since the mineral acids act entirely as local irritants, it may be inferred that their poisonous effects will be prevented by neutralizing them. But in applying that principle to the treatment, it is necessary to bear in mind their extremely rapid operation ; for if much time is lost in seeking for an antidote, irreparable mischief may be caused before the remedy is taken. Should it be possible then to administer chalk or magnesia without delay, these are the antidotes which ought to be preferred. But if it will consume time to get them, then a solution of soap, an article more likely to be at hand, should be administered, and while it is in preparation the acid should be diluted by the free use of any mild fluid, milk or oleaginous matters being preferred. The carbonates of the alkalies are by no means eligible antidotes, being themselves possessed of corrosive properties. After the proper antidote has been given to a sufficient extent, the use of diluents ought to be continued, as they render the vomiting more easy.

" The treatment of the supervening inflammation does not differ from that of ordinary inflammation of the stomach."

On this subject we may remark, that chalk is, for many reasons, the best remedy here ; and it should never be forgotten, that it is always at hand in the ceiling and walls of every apartment. The first thing, then, to be done is, to break off a piece of plaster from the wall, grind it to coarse powder in the quickest manner, and administer it in suspension in water or milk. It must, however, be recollected, that in the case of the nitric and muriatic acids, the resulting compounds, the nitrate and muriate of lime, are themselves highly destructive to animal life; we should, therefore, as soon as possible, follow up the administration of the chalk by draughts of broth or milk containing the phosphate of soda in solution: an insoluble phosphate of lime is thus generated, and every trace of the poisonous agent is removed.

The corrosive effects of Iodine may be considerably alleviated by the immediate use of starch in its ordinary form, or in that of any amylaceous substance, as wheat, flour, potatoes, &c. An iodide of starch is thus formed, which may be extricated by vomiting more easily than the iodine itself, and which being rapidly converted into hydriodic acid in the alimentary canal, is eliminated quickly through the various excretory channels.

In poisoning by Chlorine taken in solution into the stomach, or by chloride of lime, the use of the bicarbonate of soda in water as hot as it can be borne, seems to afford some encouragement, by converting the excess of chlorine into muriate of soda. No experiments, however, are yet recorded, to prove the efficiency of this treatment.

Oxalic Acid, the next poison enumerated by the author, finds a certain antidote in the carbonate of lime or magnesia. It is to be remarked, however, that the oxalates (which are nearly of equal virulence) are not thus decomposed. We therefore recommend, as an invaluable remedy in these cases, the *solution* of the bicarbonate of magnesia, invented by Dr. Murray, of Belfast, which precipitates the acid itself and all its soluble combinations. In the treatment of poisoning with the

Fixed Alkalies, we find two certain chemical remedies in acetic acid and oil; the latter appears to be preferable, as it combines the effect of a mechanical demulcent with its chemical virtue. It is almost needless to observe, that a soap is formed by the combination. In poisoning by AMMONIA or its carbonates, acetic acid is preferable, as the amoniacal soaps are of a very irritating nature.

A very important set of poisons comes next in order, viz. the SULPHURETS OF THE ALKALIES. These, it will be recollected, long held great reputation as antidotes themselves, but it has been of late satisfactorily established, that in such small doses as three drachms, they are capable of inducing fatal symptoms, depending, it is probable, on the rapid disengagement of sulphuretted hydrogen gas. Dr. Christison cites a case, according to the results of which it would appear, that the use of the chloride of lime or soda will effect a cure by decomposing the sulphuretted hydrogen as quickly as it is evolved, —the chlorine uniting with the hydrogen, and the sulphur being set free.

Notwithstanding the decided proofs that recently-prepared sulphurets are themselves strong poisons, yet I think there is some reason to regret that in the revolutions of fashion, they should have nearly been discarded from the list of our chemical auxiliaries in the treatment of metallic poisoning. Besides their own poisonous energy, it has been alleged, that the insoluble compounds which they generate in all deleterious metallic solutions, are also poisonous themselves. The sulphuret of arsenic, for example, is instanced as being an agent nearly as virulent as the arsenious acid.

I believe that this objection to the sulphurets is not founded on sufficiently comprehensive views of their various relations. In the first place, it is evident that the quantity of the sulphuret of potash, which would prove fatal *per se*, would produce no bad effect if it encountered in the alimentary canal a metallic solution, lead, bismuth, copper, silver, or tin, for example, with each of which it enters into combinations insoluble in the intestinal fluids. It is thus manifest, that if we are called to a case in which we are told that half an ounce of the acetate of lead has been swallowed, we may safely administer the sulphuret of potash beyond the dose in which it would by itself prove fatal, inasmuch as all the sulphuretted hydrogen extricated from it, is instantly absorbed by the acetate of lead, and an insoluble sulphuret of that metal produced.

Secondly, it certainly is an error to suppose, that the metallic sulphurets are generally poisonous themselves. The source of this mistake is, we believe, to be traced to the ascertained fact, that the sulphuret of arsenic is beyond all doubt nearly as destructive as the arsenious acid; but this I am inclined to regard as the exception, not as the general rule, and it unquestionably depends on the solvent power which the gastric fluids are capable of exercising over this sulphuret, but which they do not exert in any other instance. Thus Orfila has established, that half an ounce of the black sulphuret of mercury has no effect whatever on dogs. The red or orange sulphurets of antimony are also inert, compared with the other preparations of this metal. Dr. Duncan, of Edinburgh, was every year accustomed to prove this fact to his clinical pupils, by giving it in scruple doses twice or three times a day. We have ourselves given twice that quantity without any effect, beyond slight nausea, and it is probable that as much brick-dust would have been equally energetic. The case of Dr. Duffin, too, is fresh in the recollection of the profession; this gentleman having accidentally taken a poisonous dose of tartar emetic, was successfully treated by Dr. Duncan with the sulphuret of potash. We had ourselves a precisely similar case in one of our own servants, who accidentally swallowed a solution of forty grains of tartar emetic; no vomiting had ensued for fifteen minutes when she was first seen; ten grains of the sulphuret of potash were administered every quarter of an hour till the sixth dose, when she vomited a large quantity of the red sulphuret of antimony, and in six hours was perfectly well.

The sulphuret of copper still more decidedly exemplifies the correctness of these opinions. Orfila gave an ounce of it to a dog, without any effect being produced. If long kept it becomes oxidated, it is true, but it will be remembered that the sulphuret of potash forms it *at once* in the stomach, where it is effectually beyond the reach of oxidation, at least for the short time it remains within that viscus.

The same observations apply with increased force to tin, zinc, bismuth, silver, gold, platinum, and lead. Not one of the sulphurets thus formed acts as a poison, and though the sulphuret of potash would, it is true, produce dangerous symptoms if given in large quantities to a person whose alimentary canal is free from those metals, yet if the metallic solution or compound be present, the noxious influence of both is counteracted, and a harmless compound results. For these several reasons I do not hesitate to recommend the sulphuret of potash as an effectual antidote to the preparations of copper, zinc, antimony, tin, lead, bismuth, mercury, platinum, and gold. It will be valuable, especially, in the numerous instances in which we are without any information respecting the actual poison which has been taken, and in cases where a mixture of different metallic poisons has been given, (and such an instance of atrocious cunning is on record,) it is our most comprehensive, if not our only auxiliary. It will seldom or never be necessary to employ more than a drachm or two of the sulphuret, which should be given in divided doses of ten grains in solution, repeated every ten minutes or quarter of an hour. The effects produced must be carefully watched, and nothing can justify the practitioner in leaving the patient while the antidote is employed.

I proceed to enumerate the several other antidotes which have acquired reputation in the treatment of poisoning by metallic preparations.

Albumen possesses undoubted efficacy in cases of poisoning by *corrosive sublimate*, which it reduces to the condition of calomel. In poisoning with the soluble salts of copper it exerts a somewhat similar but less decided action, for while in the former a proto-chloride is formed, a compound insoluble in the acids of the stomach, in the latter *an oxide* is produced, which is readily separated by weak acetic or muriatic acid from the coagulated albumen with which it is combined. Albumen is, however, of essential service in this, as in many other forms of poisoning, by mechanically enveloping the noxious substance, and causing it to be more readily ejected from the alimentary canal. With zinc, tin, bismuth, gold and silver, albumen acts in both ways, thus specified, and it is especially useful in cases where the stomach pump is applied: it does not cause any decomposition of the salts of lead, platinum, or arsenic, or tartar emetic, and is consequently less universal in its applications than the sulphuret of potash.

The FERRO-CYANATE OF POTASH is another substance which exerts a very extended action over the metallic poisons, and which has not received from toxicologists in general the attention it deserves. For copper in all its forms it affords a perfect antidote. It likewise decomposes the soluble salts of mercury, lead, tin, antimony, silver, and gold, causing with them insoluble precipitates; but it does not decompose some of the more insoluble preparations of these metals, which are nevertheless capable of acting as destructive poisons. The ferrocyanate of potash has itself no poisonous properties.

The ALKALINE CARBONATES once obtained general confidence as antidotes to the metallic poisons; they should, however, never be resorted to, because all the precipitates which they occasion in metallic solutions are soluble in the gastric fluids and weak acids, and, moreover, their operation does not extend to the insoluble poisons. Thus, if we treat a patient who has taken the acetate of lead with the carbonate of soda, carbonate of lead is thrown down; but this is still more deleterious than the acetate itself.

Of VEGETABLE GLUTEN it is sufficient to observe that its virtues are similar to, but weaker than, those of albumen.

I have next to consider a few particular metallic poisons which have antidotes peculiar to themselves. The soluble salts of lead are thus effectually counteracted by the phosphate or sulphate of soda, which throws down a thoroughly insoluble phosphate or sulphate of lead. These antidotes, however, do not operate on the carbonate of lead, or the yellow or red oxides of that metal.

The *soluble* BARYTIC salts are rendered innocent by the sulphates, which throw down an insoluble sulphate of baryta. The carbonate, however, is not interfered with by these reagents.

Of the antimonial salts, TARTAR EMETIC is said to find an antidote in Peruvian BARK, and some cases are recorded of the success of this remedy. It is, however, rather inconsistent with the virtues of the bark in this respect, that Dr. Duncan and many other physicians are in the habit of prescribing tartar emetic in a decoction of bark without the antimonial action being at all impaired. I would, in every instance, prefer the sulphuret of potash.

For ARSENIC, the *hydrated peroxide of iron* is becoming daily of more celebrity. Since the pages on Arsenic in the body of the book were printed, several additional cases of its successful administration have been published in Europe. I proceed to the consideration of the few organic poisons which are asserted to possess antidotes peculiar to themselves.

The first in order of these is the HYDROCYANIC or PRUSSIC acid, for which ammonia and chlorine have been strenuously recommended. When we recollect, however, that Prussic acid is one of those poisons which retains its destructive power in all its soluble combinations, we cannot repose any confidence on amonia *as a chemical antidote*, though we consider it of the utmost value as a powerful diffusible stimulant, by which the narcotism induced by the acid is opposed. The second remedy chlorine, combines high chemical and physical powers; by the first it decomposes the prussic acid, and prevents it doing further harm, while by its stimulating properties, it contributes to obviate the *effects* the poison has already induced. The best mode of using this antidote is by inhaling the vapour of its solution in water sufficiently diluted. The chloride of lime in solution may at the same time be taken into the stomach. It should not, however, be forgotten that insensibility will usually have occurred before medical assistance is obtained; in this case inhalation is impossible; we can only inject the solution of the chlorine into the stomach. It would be easy, however, to contrive an apparatus by which artificial respiration might be carried on, and chlorine mingled with the air introduced.*

For OPIUM we possess no antidote of any effect. The alkaline carbonates have been recommended on the grounds of their precipitating morphia from its solutions. They, however, leave the narcotine dissolved, and the precipitate which they do occasion is itself a poison of great energy.

The last class of poisons for which we have reason to believe an antidote to exist, is thus alluded to by Dr. Christison :—

"Very lately *M. Donné* of Paris has stated that he has found iodine, bromine, and chlorine, to be antidotes for poisoning with the alkaloid of nux-vomica, as well as for the other vegetable alkaloids. Iodine, chlorine, and bromine, he says, form with the alkaloids compounds which are not deleterious,—two grains and a half of the iodide, bromide, and chloride of strychnia, having produced no effect on a dog. Animals which had taken one grain of strychnia, or two grains of veratria, did not sustain any harm, when tincture of iodine was administered immediately afterwards. But the delay of ten minutes in the administration of the antidote rendered it useless. In the compounds formed by these antidotes with the alkaloids, the latter are in a state of chemical union, and not decomposed. Sulphuric acid separates strychnia, for example, from its state of combination with chlorine, iodine, or bromine, and forms sulphate of strychnia, with its usual poisonous qualities. It remains to be proved that the

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* The best of all remedies is the cold affusion, and it should be used along with the antidote just described.

same advantages will be derived from the administration of these antidotes in the instance of poisoning with the crude drug nux-vomica, as in poisoning with its alkaloid."

I have made numerous experiments at the Medical College on the administration of Iodine to animals poisoned by brucine, nux-vomica nut, and bark, but in no instance was any good effect produced.

I have now presented the student with a sufficient summary of all that is yet known on the chemical treatment of poisoning. The mechanical and physiological treatment does not fall with in the object of these papers. I may remark, however, that cases daily occur in which the utility of the stomach-pump is more and more established, and which seem nearly to prove the universality of its application.

APPENDIX.

PART III.

ON THE BLOW-PIPE—ITS USES IN ANALYSIS, AND IN THE WORKING OF GLASS.

The subsequent pages have been compiled from three sources,—Reid's Practical Chemistry—Children's translation of Berzelius on the Blow-pipe—and Danger's *L'Art du Souffleur à la Lampe,* translated in the first volume of the Polytechnic Library.

The blow-pipe is an instrument of great value, both to the practical chemist and the student, assisting the former in his analytical investigations, and often enabling him to obtain in a few minutes, and without the assistance of any more complicated apparatus, all the information he may desire, while the student who knows how to use it, may, at little or no expense, either of time or materials, perform a very wide and interesting range of experiments, which will impress upon his mind the most important chemical relations of the materials with which he operates. It is also the instrument with which tube apparatus is made, which will be attended to in the following chapter.

For all ordinary purposes, a common brass blow-pipe will be found quite sufficient, if it be well made, and the aperture at the extremity, which need not exceed the fortieth of an inch in diameter, round and smooth; it should be tipped with ivory, where it is held in the mouth; the hollow conical vessel serving not only to condense the moisture of the breath, which is often found troublesome in working with the common blow-pipe, but also to regulate the pressure.

The first thing that the student ought to do with the blow-pipe, should be to learn to keep up a continued blast at a candle with his mouth, while he breathes freely through his nostrils. For this purpose, he must, in the first place, distend his cheeks like a trumpeter, and breathe solely through his nostrils, never allowing his cheeks to collapse. When he can do this easily, he should put a blow-pipe with a very small aperture into his mouth, placing the pointed extremity in the flame of a candle; during expiration, a small part of the expired air will pass through the tube, and during inspiration, also, air will continue to pass through the tube, if he shall have made his cheeks sufficiently tense and elastic, by distending them previously with air, and the same process goes on at each successive expiration and inspiration. Such is the mechanical rule for learning the method of keeping up a continued blast of air with this instrument. It seldom fails in enabling the beginner to acquire this art in five or ten minutes; and as considerable practice is necessary before he can be able to use it freely, he cannot commence too early with it. At first, he should take it up frequently at intervals of an hour or two, and not continue working with it for more than a quarter of an hour; he will soon, however, learn to keep up a continued blast without any difficulty, or distending his cheeks so much as to make it feel tiresome. It is necessary, indeed, to do so, only when he begins, as he will not otherwise be able to acquire the method of blowing speedily.

During inspiration, the passages connecting the mouth with the lungs and the nostrils, are completely closed, and the blast kept up solely by the air, from the reservoir within the cheeks, from which it is pressed out by the contraction of the muscles, and the stock renewed at each successive expiration.

When it is necessary to heat an extensive surface, a blow-pipe with a wider aperture should be used, and held at a little distance from the flame, or the blast made to strike upon the wick, when a lamp or candle is employed. On the other hand, when it is necessary to concentrate the heat upon a single point, the extremity of the blow-pipe should be introduced a little way within the flame, so as to give a well-defined and luminous cone, surrounded by a wavering flame, which projects beyond it; the interior portion has a blue colour, while the exterior is much lighter, and possesses very different properties, the point of greatest heat being at the extremity of the interior or blue cone.

The inner flame is usually termed the *deoxidating flame*, containing less air than is necessary for the combustion of the inflammable matter, of which it is principally composed; any substance that is placed within it being subjected, not only to a high temperature, but also to the action of the excess of inflammable matter, which has a great affinity for oxygen. Any substance placed in the exterior flame, again, which contains more air than is necessary for the combustion of the inflammable matter, is exposed to the action of the excess of oxygen at a high temperature, and it is accordingly usually termed the *oxidating flame*.

The effect produced by the flame of the blow-pipe depends very much not only upon the management of the flame, but also upon the nature of the support on which the substances that may be examined with this instrument are placed. A charcoal support not only increases the heat, but assists materially in deoxidating a number of compounds. Supports made of earthenware, again, favour the action of the oxidating flame. A small platina spoon is often necessary, and platina foil and platina wire are frequently employed.

Alder-wood charcoal is better than most other kinds, being very soft, and easily procured free from rents; when common charcoal is used, the bark should be carefully removed, as it is extremely apt to fly off in sparks before the flame of the blow-pipe, occasioning serious injury to the eyes. For a support of earthenware, flat tiles of fire clay are very useful, which may be made about six inches square, and half an inch thick, breaking a small piece of one of these, about the size of a shilling, with a hammer; the rough fractured surface always presents some point or depression on which the substance to be operated with may be placed. Pumice stone is frequently employed for the same purpose, but is too porous for a number of operations.

Though the mouth blow-pipe is sufficient for all ordinary purposes, many contrivances have been made for increasing its power, and avoiding the necessity of supplying the stream of air for the blast by the lungs, one or two of which may now be mentioned, along with some useful modifications in the method of applying the heat.

In the water pressure blow-pipe, the method of constructing which will be understood from the figure in the plate, a cylindrical iron vessel is placed within a cistern of water, two tubes being fitted to the upper part, and a wide opening made below, so that there may be a free communication between the water within the cylinder, and the rest of the water in the cistern. When the bellows are worked, air is forced into the cylinder through the tube connected with them, a valve preventing its return, the water forced out of the cylinder rising in the cistern. On opening the stop-cock connected with the other tube attached to the top of the cylinder, the water returns slowly to its original level, and if made to pass through a blow-pipe aperture of the usual size, a cylinder capable of containing a cubic foot of air, will give a continued stream of air for upwards of ten minutes, which may be renewed from time to time, as it is required. (See Plate.) A large lamp fed by tallow should be used with this blow-pipe, the wick being made about an inch thick, and separated at the top to the depth of a quarter of an inch to extend the flame, the point of the *nozzle*, which is usually made of glass, being introduced a little way within it. The glass nozzle is fitted to the bent brass tube, (continuous with the upper part of the stop-cock,) merely by tying it round with thread, and pressing it gently in, when it has been made to fit to it. The stop-cock is fixed in a ball and socket-joint, so that it may be moved easily in any direction.

For a full detail with respect to the method of using the mouth blow-pipe, we must refer to the treatises which have been written on this subject, mentioning only a few experiments which will enable the beginner to commence experiments with it, and subjoining a table of the effects which it produces on inorganic substances, taken from Mr. Children's translation of Berzelius's Essay on the use of the Blow-pipe. The size of the substance submitted to the flame of the blow-pipe need not be larger than a pea, and in most cases it will be found advantageous to take a much smaller portion; this, however, must be regulated in a great measure by the nature of the substance to be operated on, the size of the flame which can be commanded, and the dexterity of the experimenter.

Take a small piece of lead, not exceeding half a grain, and expose it to the oxidating flame on a fragment of a broken tile; when it is melted, a beautiful iridescent appearance will be seen on its surface, the lead speedily attracting oxygen and being converted into the yellow oxide of lead, which is melted at the same time, and forms a glazing over the earthenware.

Expose another piece of lead to the deoxidating flame, and if it be completely surrounded with this part of the flame, no oxide will be formed.

Put some red oxide of lead on a piece of tile, and expose it to heat in the outer flame; it will part with a portion of its oxygen at this high temperature, and be converted into the yellow oxide of lead, though surrounded with an excess of oxygen; but it will not part with any more oxygen, though the heat may be sufficient to melt what remains.

Put another portion of this oxide on a piece of charcoal to assist its reduction by the deoxidating flame; globules of metallic lead will be immediately obtained. Expose some metallic antimony to heat on charcoal in the usual manner;

it will soon melt, revolve rapidly round its centre, and burn with a pale blue flame, producing a large quantity of white fumes.

*Z*inc treated in the same manner burns with its characteristic rich-coloured flame. Expose some borax to heat on a tile, and continue the heat till the water of crystallization is expelled and a bead of glass obtained.

Repeat this several times, mixing the borax successively with portions of the peroxide of copper, peroxide of manganese, oxide of chrome, chloride of gold, and a number of other substances. The glass that is formed in this manner will be rendered bluish-green by the peroxide of copper, purple by the peroxide of manganese, green by the oxide of chrome, and of a beautiful pink colour by the chloride of gold. A large piece of borax receives a very deep tint when it is merely touched with a glass rod dipped in a very dilute solution of the chloride of gold.

Expose some metallic tin to the flame of the blow-pipe; it will soon be melted and acquire a crust of oxide on its surface; then endeavour to reduce the oxide on charcoal. This will not be easily effected, unless the operator has acquired considerable command over the blow-pipe, but if a little carbonate of soda or potass be put over the oxide of tin, globules of metallic tin may be obtained with great facility.

These experiments will be sufficient to guide the student in studying the subjoined table, from which he should select and perform all those that may appear most interesting.

The great value of borax as a flux, depends principally upon its tendency to form very fusible compounds with a number of substances, after its water of crystallization has been expelled, from the appearance of which their nature may in general be inferred. SUBCARBONATE of soda is used for the same purpose, and also to promote the reduction of metallic oxides. Phosphate of soda and ammonia (salt of phosphorus) is prepared by mixing equal parts of phosphate of soda and phosphate of ammonia in solution, crystallizing afterwards by evaporation, or exposure to heat at the blow-pipe ; the ammonia is disengaged, and the excess of acid now in combination with the soda combines with salifiable bases, and renders them more easily fusible. **Nitre** imparts oxygen readily ; **Tin**, again, is used as a deoxidating agent ; **Iron** precipitates many metals, as copper, lead, and antimony ; and **Nitrate of Cobalt** serves to distinguish alumina from magnesia, producing a blue colour with the one, and a rose-red with the other.

SYNOPTIC TABLE
OF
THE PRINCIPAL CHARACTERS
OF
THE EARTHS AND METALLIC OXIDES BEFORE THE BLOW-PIPE, EXTRACTED FROM BERZELIUS' TREATISE ON THE BLOW-PIPE, AS TRANSLATED BY MR. CHILDREN.

ABBREVIATIONS.—O. F. *Oxidating Flame.*—R. F. *Reducing* or *Deoxidating Flame.* — = parts *Equal parts of the Assay and Flux.*—N. C. *Nitrate of Cobalt.*—Fl. *Flaming.*—*C. under the column of either of the Fluxes, means that the support is charcoal.*—P. F. *Platina Foil.*—P. W. *Platina Wire.*—A Brace {, *refers to the first column only, and includes all those which are contained in the space it comprehends.*

	Heated alone on	
Assay.	Platina.	Charcoal.
1. Alkalies.		
2. Baryta.	2. Infusible.	2. Infusible.
a. Hydrate.	*a.* Bubbles up and fuses.	*a.* Is absorbed.
b. Carbonate.	*b.* Fuses readily into a clear glass enamel, white on cooling.	*b.* Becomes caustic and is absorbed.
3. Strontia.	3. Infusible.	3. Infusible.
a. Hydrate.	*a.* Like baryta.	
b. Carbonate.	*b.* Fuses with moderate heat at the surface,—great brilliancy; tinges strong R. F. red; becomes alkaline.	
4. Lime.	4. No. change.	
a. Carbonate.	*a* Becomes caustic and alkaline; emits brilliant white light.	
5. Magnesia.	5. No change.	5. No change.
6. Alumina.	6. No change.	6. No change.
7. Glucina.	7. No change.	7. No change
8. Yttria.	8. Like Glucina.	8. Like Glucina.
9. Zirconia.	9. Infusible; emits intense light.	9. Infusible; emits intense light.
10. Silica.	10. No change.	10. No change.

	Heated alone on	
Assay.	Platina.	Charcoal.
11. Molybdic acid.	11. Fumes and fuses brown-yellow on cooling; in R. F. blue; intense heat, brown.	11. Fuses, and is absorbed, and partly reduced.
12. Tungstic acid.	12. R. F. blackens, but not reduced.	12. The same.
13. Oxide of chrome	13. No change.	13. The same.
14. Antimony.		14. Fuses readily; white fumes, which condense into pearly crystals.
a. Oxide of Antimony.	*a.* Fuses readily, and sublime in white fumes; *precipitated oxide* burns like tinder into antimonious acid.	*a.* Fuses readily, and reduces; colours the flame greenish.
b. Antimonious Acid.		*b.* Does not fuse, nor reduce; gives a bright light.
c. Antimonic Acid.		*c.* Whitens; is changed to antimonious acid.
15. Oxide of Tellurium.	15. F. fuses and fumes.	15. Fuses, effervesces, and reduces.
16. Oxide of Columbium.	16. No change.	16. The same.
17. Oxide of Titanium.	17. No change.	17. The same.
18. Oxides of Uranium.		18. Peroxide becomes protoxide; blackens, but does not fuse.
19. Oxides of Cerium.	19. Protoxide becomes Peroxide.	19. Peroxide does not alter.
20. Oxide of Manganese.		20. Not fused; becomes brown in a strong heat.
21. Oxide of Zinc.	21. Yellow while hot; white when cold; does not fuse, but gives out great light when very hot, and white fumes, which condense like wool.	
22. Oxide of Cadmium.	22. F. no change.	22. Soon dissipates, leaves a red or orange yellow powder on the charcoal.
23. Oxide of Iron.	23. O. F. no change.	23. R. F. blackens, and becomes magnetic.
21. Oxide of Cobalt.	24. No change.	24. The same.

Assay.	Heated alone on Platina.	Heated alone on Charcoal.
25. Oxide of Nickel.	25. No change.	25. The same.
26. Bismuth.		26. Flies off in fumes, and leaves a mark with red or orange edges, which may be dissipated in R. F. without giving colour to the flame.
a. Oxide of Bismuth.	*a.* P. F. fuses readily mass dark brown, yellowish on cooling. In very intense heat reduces and perforates the foil.	*a.* Instantly reduced.
27. Oxides of Tin.	27. Protoxide takes fire, and burns like tinder into peroxide.	27. R. F. Peroxide does not fuse, but reduces in a strong prolonged heat.
28. Oxide of Lead.	28. Minium becomes black while hot; at incipient redness changes to yellow oxide, fusible into orange coloured glass.	28. Orange glass reduces into a globule of lead.
29. Oxide of Copper.		29. O. F. black globule; flows over the charcoal; under surface reduces. R. F. reduces; with strong heat gives a bead of metal.
30. Oxide of Silver.	30. Instantly reduced.	30. Instantly reduced.

Assay.	**Heated with Fluxes. Soda.**	**Heated with Fluxes. Borax.**	**Salt of Phosphorus.**
1. Alkalies.			
2. Baryta. ***a. Hydrate.*** ***b. Carbonate.***	**2. *a.* *b.* Fuse, and are absorbed by the charcoal.**	**2. *a.* *b.* Fuse readily with effervescence into a clear glass, which becomes opaque by Fl.**	**2. *a.* *b.* As with borax, but foam and intumesce; end in a clear glass.**
3. Strontia. ***a. Hydrate.*** ***b. Carbonate.***	**3. No action on caustic strontia *b.* = parts, fuses**	**3. *a.* *b.* Like Baryta.**	**3. *a.* *b.* Ditto.**

Assay.	Heated with Fluxes.		Salts of Phosphorus.
	Soda.	Borax.	
	into a clear glass, becomes milky on cooling: in strong heat, bubbles, and is absorbed by the charcoal.		
4. Lime. a. *Carbonate.*	4. } No sensible a. } quantity dissolved.	4. Clear glass; opaque by Fl. a. Fuses with effervescence; with more carbonate clear glass; crystallizes on cooling.	4. Fuses in large quantity; clear glass. a. Fuses with effervescence.
5. Magnesia.	5. No action.	5. Like lime.	5. Fuses readily: clear glass: saturated with magnesia, opaque on cooling.
6. Alumina.	6. Swells up; forms an infusible compound.	6. Fuses slowly; permanently clear glass.	6. Permanently clear glass.
7. Glucina.	7. No action.	7 Clear glass, with a large proportion of the assay; opaque by Fl.	7. As with Borax.
8. Yttria.	8. Like Glucina.	8. Like Glucina.	8. Like Glucina.
9. Zirconia.	9. Similar to Glucina.	9. Like Glucina.	9. Like Glucina, but dissolves more difficultly.
10. Silica.	10. Fuses with brisk effervescence; clear glass.	10. Fuses very slowly; permanently clear glass.	10 Very small portion dissolves; clear glass.
11. Molybdic Acid.	11. P. W. effervesces, clear glass; becomes milky on cooling. C. fuses, absorbed and reduced.	11. P. W. clear glass in O. F. C. and in R. F. glass becomes dirty brown, but not opaque.	11. P. W. and in O. F. greenish glass while hot; colourless, cold. In R. F. becomes opaque: dull blue while hot: clear and fine green on cooling. C. same phenomena.
12. Tungstic Acid.	12 P. W. dark yellow glass;	12. P. W. and O. F. clear glass;	12. O. F. yellowish glass.

Assay.	Heated with Fluxes.		Salt of Phosphorus.
	Soda.	Borax.	
	crystallizes on cooling: opaque white or yellowish. C. and R. F. reduced.	not opaque by Fl. R. F. glass becomes yellow.	R. F. fine blue glass.
13. Oxide of Chrome.	13. P. W. and O. F. dark orange glass: opaque and yellow on cooling. R. F. opaque; glass green on cooling. C. absorbed, but not reduced.	13. C. fuses difficulty, glass emerald green; on P. W. and O. F. the colour flies & glass becomes brown yellow; on cooling, assumes a faint green tinge.	13. Green glass in both flames.
14. Antimony. a. *Oxide of Antimony.*	a. P. W. fuses; clear colourless glass, becomes white on cooling. C. is reduced.	a. C. dissolves in large quantity; glass, yellowish, hot; almost colourless cold. If saturated, part reduced and sublimed; strong R. F. the glass becomes opaque and greyish.	a. P. W. and O. F. glass, yellowish, hot, colour flies on cooling.
15. Oxide of Tellurium.	15. P. W. colourless glass; white on cooling. C. reduced.	15. P. W. clear, colourless glass, white on cooling. C. becomes grey and opaque.	15. The same.
16. Oxide of Columbium.	16. Combines with effervescence, but not fused or reduced.	16. Colourless, clear glass; becomes opaque by Fl.	16. Fuses easily; glass, permanently clear.
17. Oxide of Titanium.	17. Fuses into a clear dark yellow glass; white or grey on cooling, and crystallizes with evolution of great heat. C. not reducible.	17. P. W. fuses easily; glass colourless; becomes milk white by Fl. R. F. glass assumes a dark amethyst colour but transparent.	17. O. F. clear, colourless glass. R. F. and on C. glass, yellowish, hot; on cooling, first red, then very fine bluish violet.

Assay.	Heated with Fluxes.		Salt of Phosphorus.
	Soda.	Borax.	
		In large quantity on C. and R. F. glass, dull yellow; when cold, deep blue.	
18. Oxides of Uranium.	18. C. brown yellow; not fused.	18. P. W. Dark yellow glass; in R. F. becomes dirty green.	18. P. W. and O. F. clear yellow glass; cold, straw yellow, slightly green. C. and R. F. fine green glass.
19. Oxides of Cerium.	19. C. not fused, soda absorbed; white or grey, white protoxide remains on the surface.	19. O. F. fine red, or deep orange yellow glass; colour flies on cooling; cold yellowish tint. Enamel white. by Fl. In R. F loses its colour.	19. O. F. fine red glass; colourless when cold, and quite limpid.
20. Oxide of Manganese.	20. P. F. fuses, green glass, clear; cold, bluish green. C. not reduced.	20. O. F. clear, amethyst colour glass; colour flies in R. F.	20. The same, but colour not so deep. Infusion in O. F. boils and gives off gas. In R. F. fuses quietly.
21. Oxide of Zinc.	21. C. not fused, but reduced, white fumes which cover the charcoal.	21. O. F. fuses easily, clear glass becomes milky by Fl.	21. Nearly the same.
22. Oxide of Cadmium.	22. P. W. not fused. C. reduced, sublimes, and leaves a circular yellowish mark.	22. P. F. yellowish glass, colour flies on cooling; on C. glass bubbles, cadmium reduced, sublimes and leaves yellow oxide.	22. Dissolves in large quantities, clear glass; on cooling, milk white.
23. Oxide of Iron.	23. C. absorbed and reduced: not fused.	23. O. F. dull red, glass becomes clear and yellowish or colourless by cooling.	23. Similar to borax.

	Heated with Fluxes.		
Assay.	Soda.	Borax.	Salt of Phosphorus.
		C. and R. F. bottle-green glass, or bluish green.	
24. Oxide of Cobalt.	24. P. W. pale red by transmitted light; grey, cold.	24. Fuses readily, deep blue glass.	24. The same, the colour appears violet by candle light.
25. Oxide of Nickel.	25. C. absorbed and reduced; not fused.	25. O. F. orange yellow, or reddish glass; becomes yellow or nearly colourless on cooling.	25. As with borax, but the colour flies almost wholly on cooling.
26. Bismuth. *a. Oxide of Bismuth.*		*a.* O. F. colourless glass. R. F. partly reduced, muddy greyish glass.	*a.* O. F. yellowish-brown glass hot; colourless, but not quite clear, cold. R. F. clear and colourless glass, hot; opaque, and greyish black, cold.
27. Oxides of Tin.	27. P. W. effervesces, tumefied infusible mass. C. readily reduced.	27. Fuses with great difficulty; permanently clear glass.	27. As with borax.
28. Oxide of Lead.	28. P. W. clear glass becomes yellowish and opaque on cooling. C. instantly reduced.	28. P. W. clear glass, yellow, hot; on cooling colourless. C. flows over the surface and reduces.	28. Clear colourless glass.
29. Oxide of Copper.	29. P. W. fine green glass, hot; on cooling colourless and opaque. C. absorbed and reduced.	29. O. F. fine green glass, which in R. F. becomes colourless, hot; but cinnabar-red & opaque when solid.	29. O. F. similar to borax. R. F. glass usually red, opaque, and like an enamel.
20. Oxide of Silver.		30. O. F. glass becomes milky, or opaline, on cooling. R. F. greyish.	30. O. F. yellowish glass viewed by transmitted light by day, by candle light reddish. R. F. greyish.

Assay.	With other Re-agents.	Remarks.
1. Alkalies.		1. The Alkalies are not readily distinguishable by the blow-pipe. *Lithia* leaves a dull yellow stain, when heated to redness on platina foil. *Ammonia* may be known by heating the assay with soda; it gives off a pungent vapour, which turns the yellow colour of moistened turmeric paper brown.
2. Baryta. *a. Hydrate.* *b. Carbonate.*	2. *a.* *b.* N. C.; a globule of different shades of red; colour flies on cooling.	
3. Strontia. *a. Hydrate.* *b. Carbonate.*	3. *a.* *b.* N. C. exhibit a blackish colour; do not fuse.	
4. Lime. *a. Carbonate.*	4. *a.* N. C. black or dark grey mass, infusible.	
5. Magnesia.	5. N. C.; flesh colour when quite cold.	
6. Alumina.	6. N. C. fine blue glass, with strong heat when cold.	6. The blue colour is only distinctly seen by daylight.
7. Glucina.	7. N. C.; black, or dark grey mass.	
10. Silica.	10. N. C.; blue glass when perfectly fused.	10. The part not perfectly fused with nitrate of cobalt, has a reddish blue disagreeable colour.
11. Molybdic Acid.		11. In the inclined glass tube, fuses, gives off vapour, which condenses partly on the tube as a white powder, partly on the assay in brilliant pale yellow crystals.
12. Tungstic Acid.		12. If tungstic acid contain iron, the glass with salt of phosphorus is blood-red in R. F. Tin makes it green or blue.
14. Antimony.		14. Antimony does not sublime at the fusing point of glass. On charcoal, when red, ignition continues spontaneously. In a tube open at

Assay.	With other Re-agents.	Remarks..
		both ends, it gives off white fumes.
a. Oxide of Antimony. *b. Antimonious Acid.* *c. Antimonic Acid.*		a. b. c. The oxides and acids of antimony behave alike with the fluxes.
15. Oxide of Tellurium.		15. Metallic tellurium heated in a glass matrass, first gives off vapour, and then a grey metallic sublimate of tellurium. In a tube open at both ends, emits abundant fumes which condense in a white fusible powder.
17. Oxide of Titanium.	17. N. C. black or greyish black.	
20. Oxide of Manganese.		20. A very minute portion of manganese gives a green glass with soda.
23. Oxide of Iron.		23. The reduction of iron from the peroxide to protoxide, is facilitated by tin.
24. Oxide of Cobalt.	24. With sub-carbonate of potassa, black glass when cold.	
26. Bismuth.		26. In a glass matrass does not sublime at the fusing point of glass. In an open tube scarcely gives off any fumes; the metal becomes covered with a dull brown fused oxide, of a slight yellowish tint, when cold.
30. Mercury.		30. All the compounds of mercury are volatile; mixed with tin or iron filings, and heated in a glass tube, metallic mercury distills over.
32. Gold. 33. Platina. 34. Iridium. 35. Rhodium. 36. Polladium.		32. 33. 34. 35. 36. These metals have no action on the fluxes, which can only serve to detect the foreign metals with which they may be combined. They are best examined by cupellation with lead.

CHOICE AND PRESERVATION OF GLASS.

The only materials employed in the fabrication of the objects described in this Treatise, are tubes of common glass or of flint-glass. They can be had of all diameters, and of every variety of substance, and are made of sufficiently good quality by all the native glass-blowers. You should choose tubes that are very uniform—that is to say, straight and perfectly cylindrical, both inside and outside. A good tube should have the same diameter from one end to the other, and the sides or substance of the glass should be of equal thickness in every part. This is indispensable when the tubes are to have spherical bulbs blown upon them.

The substance of the glass should be perfectly clear, without bulbs, or stripes. The tubes are so much the more easy of use, as the glass of which they are made is the more homogeneous. Under this point of view, the white glass, known in commerce by the name of crystal or flint-glass, is preferable to common glass; it is more fusible, less fragile, and less liable to break under the alternations of heat and cold; but it is dearer and heavier, and has the serious disadvantage of becoming permanently black when exposed to a certain part of the flame. This is an effect, the causes and consequences of which will be explained in a subsequent section.

PREPARATION OF TUBES BEFORE HEATING THEM.

Before presenting a tube to the flame, you should clean it well both within and without, in order to remove all dust and humidity. If you neglect to take this precaution, you run the risk of cracking or staining the glass. When the diameter of the tube is too small to permit of your passing a plug of cloth or paper to clean its interior, you can accomplish the object by the introduction of water, which must, many times alternately, be sucked in and blown out, until the tube is deemed clean. One end of it must then be closed at the lamp, and it must be gradually exposed to a charcoal fire, where, by raising successively all parts of the tube to a sufficiently high temperature, you endeavour to volatilize and expel all the water it contains. In all cases you considerably facilitate the disengagement of moisture by renewing the air in the tube by means of a bottle of Indian-rubber fastened to the end of a long narrow tube, which you keep in the interior of the tube to be dried during the time that it is being heated. You can here advantageously substitute alcohol for water, as being much more volatile, and as dissolving greasy matters; but these methods of cleaning should only be employed for valuable objects, because it is extremely difficult fully to expel moisture from a tube wherein you have introduced water, and because alcohol is too expensive to be employed where there is no particular necessity.

When the tubes no longer contain dust, or moisture, you measure them, and mark the divisions according to the sort of work which you propose to execute.

METHOD OF PRESENTING TUBES TO THE FIRE, AND OF WORKING THEM THEREIN.

The two arms are supported on the front edge of the table, and the tube is held with the hands either above or below, according as it may be necessary to employ more or less force, more or less lightness. You ought, in general, to hold the tube *horizontally*, and in such a manner that its direction may be perpendicular to that of the flame. Yet, when you wish to heat at once a large portion of the tube, or to soften it so that it shall sink together in a particular manner, as in the operation of sealing, you will find it convenient to *incline* the tube, the direction of which, however, must always be such as to turn the heated part continually towards you.

We are about to give a general rule, upon the observance of which we cannot too strongly insist, as the success of almost every operation entirely depends upon it. The rule is, *never to present a tube to the flame without* CONTINUALLY TURNING *it;* and turning it, too, with such a degree of rapidity that every part of its circumference may be heated and softened to the same degree. As melted glass necessarily tends to descend, there is no method of preventing a heated tube from becoming deformed but that of continually turning it, so as to bring the softened part very frequently uppermost. When you heat a tube near the middle, the movement of the two hands must be *uniform* and *simultaneous,* or the tube will be twisted and spoiled.

When the tubes have thick sides, they must not be plunged *into* the flame until they have previously been strongly heated. You expose them at first to the current of hot air, at some inches from the extremity of the jet; you keep them there some time, taking care to turn them continually, and then you gradually bring them towards, and finally into the flame. The thicker the sides of the tubes are, the greater precaution must be taken to elevate the temperature gradually: this is the only means of avoiding the fractures which occur when the glass is too rapidly heated. Though it is necessary to take so much care with large and thick tubes, there are, on the contrary, some tubes so small and so thin that the most sudden application of the fire is insufficient to break them. Practice soon teaches the rule which is to be followed with regard to tubes that come between these extremes.

Common glass ought to be fused at the *maximum* point of heat; but glass that contains oxides capable of being reduced at that temperature (such as flint-glass) require to be worked in that part of the flame which possesses the highest oxidating power. If you operate without taking this precaution, you run the risk of decomposing the glass. Thus, for example, in the case of flint-glass, you may reduce the oxide of lead, which is one of its constituents, to the state of metallic lead. The consequence of such a reduction is the production of a black and opaque stain upon the work, which can only be removed by exposing the glass, during a very long time, to the extremity of the jet.

You must invariably take the greatest care to keep the flame from passing into the interior of the tube; for when it gets there it deposits a greasy vapour, which is the ordinary cause of the dirt which accumulates in instruments that have been constructed without sufficient precaution as to this matter.

In order that you may not blacken your work, you should take care to snuff the wick of the lamp whenever you perceive the flame to deposit soot.

You can judge of the *consistence* of the tubes under operation as much by the *feel* as by the *look* of the glass. The degree of heat necessary to be applied to particular tubes, depends entirely upon the objects for which they are destined. As soon as the glass begins to feel soft, at a *brownish-red heat*, for example, you are at the temperature most favorable to good *bending*. But is it intended to *blow a bulb?* The glass must, in this case, be completely melted, and subjected to a full *reddish-white heat*. We shall take care, when speaking hereafter of the different operations to be performed, to mention the temperature at which *each* can be performed with most success.

When an instrument upon which you have been occupied is finished, you should remove it from the flame *gradually*, taking care to *turn* it continually, until the glass has acquired sufficient consistence to support its own weight without becoming deformed. Every instrument formed thus of glass requires to undergo a species of *annealing*, to enable it to be preserved and employed. To give the instrument this annealing, it is only necessary to remove it from the flame very gradually, allowing it to repose some time in each *cooler* place to which you successively remove it. The thicker or the more equal to the sides of the glass, the more carefully it requires to be annealed. No instrument should be permitted to touch cold or wet bodies while it is warm.

FUNDAMENTAL OPERATIONS IN GLASS-BLOWING.

All the modifications of shape and size which can be given to tubes, in the construction of various instruments, are procured by a very small number of operations.

These fundamental operations can be reduced to ten, which may be named as follows :—

1. Cutting.
2. Bordering.
3. Widening.
4. Drawing out.
5. Choking.
6. Sealing.
7. Blowing.
8. Piercing.
9. Bending.
10. Soldering.

1.—CUTTING.

The different methods of cutting of glass tubes which have been contrived, are all founded on two principles; one of these is the division of the surface of glass by cutting instruments, the other the effecting of the same object by a sudden change of temperature; and sometimes these two principles are combined in one process.

The first method consists in notching the tube, at the point where it is to be divided, with the edge of a file, or of a thin plate of hard steel, or with a diamond; after which, you press upon the two ends of the tube, as if to enlarge the notch, or, what is better, you give the tube a slight smart blow. This method is sufficient for the breaking of small tubes. Many glass-blowers habitually employ an agate, or a common flint, which they hold in one hand, while with the other they rub the tube over the sharp edge of the stone, taking the precaution of securing the tube by the help of the thumb. For tubes of a greater diameter, you can employ a fine iron wire stretched in a bow, or, still better, the glass-cutter's wheel; with either of these, assisted by a mixture of emery and water, you can cut a circular trace round a large tube, and then divide it with ease.

When the portion which is to be removed from a tube is so small that you cannot easily lay hold of it, you cut a notch with a file, and expose the notch to the point of the blowpipe flame; the cut then flies round the tube.

This brings us to the second method of cutting tubes—a method which has been modified in a great variety of ways. It it founded on the property possessed by vitrified matter of breaking when exposed to a sudden change of temperature. Acting upon this principle, some artists apply to the tube, at the point where they desire to cut it, a band of fused glass. If the tube does not immediately separate into two pieces, they give it a slight smart blow on the extremity, or they drop a little water on the heated ring. Other glass-blowers make use of a piece of iron heated to redness, an angle or a corner of which they apply to the tube at the point where it is to be cut, and then, if the fracture is not at once effected by the action of the hot iron, they plunge the tube suddenly into cold water.

The two methods here described can be combined. After having made a notch with a file, or the edge of a flint, you introduce into it a little water, and bring close upon it the point of a very little tube previously heated to the melting point. This double application of heat and moisture obliges the notch to fly right round the tube.

When the object to be cut has a large diameter, and very thin sides—when it is such a vessel as a drinking-glass, a cup, or a gas tube—you may divide it with much neatness by proceeding as follows. After having well cleaned the vessel, both within and without, pour oil into it till it rises to the point, or very nearly to the point, where you desire to cut it. Place the vessel, so prepared, in an airy situation; then take a rod of iron, of about an inch in diameter, make the extremity brightly red-hot, and plunge it into the vessel until the extremity of the iron is half an inch below the surface of the oil: there is immediately formed a great quantity of very hot oil, which assembles in a thin stratum at the surface of the cold oil, and forms a circular crack where it touches the sides of the glass. If you take care to place the object in a horizontal position, and to plunge the hot iron without communicating much agitation to the oil, the parts so separated will be as neat and as uniform as you could desire them to be. By means of this method we have always perfectly succeeded in cutting very regular zones from ordinary glass.

2.—BORDERING.

To whatever use you may destine the tubes which you cut, they ought, almost always, to be bordered. If you merely desire that the edges shall not be sharp, you can smoothen them with the file, or, what is better, you can expose them to the flame of the lamp until they are rounded. If you fear the sinking in of the edges when they are in a softened state, you can hinder this by working in the interior of the tube a round rod of iron. The rod of iron should be one-sixth of an inch thick; one end of it should be filed to a conical point, and the other end be inserted into a thin, round, wooden handle. You will find it convenient to have a similar rod with a slight bend in the middle.

When you desire to make the edges of the tube project, bring the end to a soft state, then insert in it a metallic rod, and move it about in such a manner as to widen a little the opening. While the end of the tube is still soft, place it suddenly upon a horizontal surface, or press it by means of a very flat metallic plate. The object of this operation is to make the end of the tube flat and uniform. The metallic rod which you employ may be the same as we have described in the preceding paragraph. Instead of agitating the rod in the tube, you may hold it in a fixed oblique position, and turn the tube round with the other hand, taking care to press it continually and regularly against the rod. Very small tubes can be bordered by approaching their extremities to a flame not acted upon by the blowpipe; particularly the flame of a spirit-lamp.

When the edges of a tube are to be rendered capable of suffering considerable pressure, you can very considerably augment their strength by soldering a rib or string of glass all round the end of the tube.—Holding the tube in the left hand, and the string of glass in the right, you expose them both at once to the flame. When their extremities are sufficiently softened, you attach the end of the rib of glass to the tube at a very short distance from its extremity; you then continue gradually to turn the tube, so as to cause the rib of glass to adhere to it, in proportion as it becomes softened. When the rib has made the entire circumference of the tube, you separate the surplus by suddenly darting a strong jet of fire upon the point where it should be divided; and you continue to expose the tube to the flame, always turning it round, until the ring of glass is fully incorporated with the glass it was applied to. You then remove the instrument from the flame, taking care to anneal it in so doing. During this operation you must take care to prevent the sinking together of the sides of the tube, by now and then turning the iron rod in its interior. It is a *red heat*, or a *brownish red heat*, that is best adapted to this operation.

3.—WIDENING.

When you desire to enlarge the diameter of the end of a tube, it is necessary, after having brought it to a soft state to remove it from the flame, and to press the sides of the glass outwards by means of a large rod of iron with a conical point. The tube must be again heated, and again pressed with the conical iron rod, until the proper enlargement is effected. This operation is much the same as that of bordering a tube with projecting edges.

4.—DRAWING OUT.

You can *draw out* or *contract* a tube either in the middle or at the end. Let us in the first place consider that a tube is to be drawn out in the middle. If the tube is long, you support it with the right hand *below*, and the left hand *above*, by which means you secure the force that is necessary, as well as the position which is commodious, for turning it continually and uniformly in the flame. It must be kept in the jet till it has acquired a *cherry-red heat*. You then remove it from the flame, and always continuing gently to turn it, you gradually separate the hands from each other and draw the tube in a straight line. In this manner you produce a long thin tube in the centre of the original tube, which ought to exhibit two uniform cones where it joins the thin tube, and to have the points of these cones in the prolongation of the axis of the tube.

To draw out a tube at its extremity, you heat the extremity till it is in fusion, and then remove it from the flame; you immediately seize this extremity with the pliers and at the same time separate the two hands. The more rapidly this operation is performed, the glsss being supposed to be well softened, the more capillary will the drawn-out point of the tube be rendered. Instead of pinching the fused end with the pliers, it is simpler to bring to it the end of a little auxiliary tube, which should be previously heated, to fuse the two together, and then to draw out the end of the original tube by means of the auxiliary tube. In all cases, the smaller the portion of tube softened, the more abrupt is the part drawn out.

When you desire to draw out a point from the side of a tube, you must heat that portion alone, by holding it fixedly at the extremity of the jet of flame. When it is sufficiently softened, solder to it the end of an auxiliary tube, and then draw it out. A *red heat*, or a *cherry-red heat*, is best adapted to this operation.

5.—CHOKING.

We do not mean by *choking*, the closing or stopping of the tube, but simply a diminution of the interior passage, or bore. It is a sort of contraction. You perform the operation by presenting to the flame a zone of the tube at the point where the contraction is to be effected. When the glass is softened, you draw out the tube, or push it together, according as you desire to produce a hollow in the surface of the tube, or to have the surface even, or to cause a ridge to rise above it. A *cherry-red heat* is the proper temperature to employ.

6.—SEALING.

If the sides of the tube to be sealed are thin, and its diameter is small, it is sufficient to expose the end that you wish to close to the flame of the lamp. When the glass is softened it sinks of itself, in consequence of the rotatory motion given to it, towards the axis of the tube, and becomes rounded. The application of no instrument is necessary.

If the tube is of considerable diameter, or if the sides are thick, you must soften the end, and then, with a metallic rod or a flat pair of pliers, mould the sides to a hemisphere, by bringing the circumference towards the centre, and continuing to turn the tube in the flame, until the extremity is well sealed, and perfectly round. Instead of this method, it is good, when the extremity is sufficiently softened, to employ an auxiliary tube, with the help of which you can abruptly draw out the point of the original tube, which becomes by that means cut and closed by the flame. In order that this part may be well rounded, you may, as soon as the tube is sealed, close the other extremity with a little wax, and continue to expose the sealed part to the flame, until it has assumed the form of a *drop of tallow*. You can also seal in this fashion, by blowing, with precaution, in the open end of the tube, while the sealed end is in a softened state.

If you desire the sealed part to be flat, you must press it, while it is soft, against a flat substance. If you wish it to be concave, like the bottom of a bottle, you must suck air from the tube with the mouth; or instead of that, force the softened end inwards with a metallic rod. You may also draw out the end till it be conical, or terminate it with a little button. In some cases the sealed end is bent laterally; in others it is twirled into a ring, having previously been drawn out and stopped in the bore. In short, the form given to the sealed end of a tube can be modified in an infinity of ways, according to the object for which the tube may be destined.

You should take care not to accumulate too much glass at the place of sealing. If you allow it to be too thick there, you run the risk of seeing it crack during the cooling. The operation of sealing succeeds best at a *cherry-red heat.*

7.—BLOWING.

The construction of a great number of philosophical instruments requires that he who would make them should exercise himself in the art of blowing *bulbs* possessing a figure exactly spherical. This is one of the most difficult operations.

To blow a bulb at the extremity of a tube, you commence by sealing it; after which, you collect at the sealed extremity more or less glass, according to the size and the solidity which you desire to give to the bulb. When the end of the tube is made thick, completely sealed, and well rounded, you elevate the temperature to a *reddish white* heat, taking care to turn the tube continually and rapidly between your fingers. When the end is perfectly soft you remove it from the flame, and, holding the tube horizontally, you blow quickly with the mouth into the open end, without discontinuing rotation for a single moment. If the bulb does not by this operation acquire the necessary size, you soften it again in the flame, while under the action of which you turn it very rapidly, lest it should sink together at the sides, and become deformed. When it is sufficiently softened you introduce, in the same manner as before, a fresh quantity of air. It is of importance, to observe that if the tube be of a large diameter it is necessary to contract the end by which you are to blow in order that it may be turned round with facility while in the mouth.

When the bulb which you desire to make is to be somewhat large, it is necessary, after having sealed the tube, to soften it for the space of about half an inch from its extremity, and then, with the aid of a flat piece of metal, to press moderately and repeatedly on the softened portion, until the sides of the tube which are thus pressed upon, sink together, and acquire a certain degree of thickness. During this operation, however, you must take care to blow, now and then, into the tube, in order to retain a hollow space in the midst of the little mass of glass, and to hinder the bore of the tube from being closed up. When you have thus, at the expense of the length of the tube, accumulated at its extremity a quantity of glass sufficient to produce a bulb, you have nothing more to do than to heat the matter till it is raised to a temperature marked by a *reddish-white* colour, and then to expand it by blowing.

Instead of accumulating the glass thus, it is more expedient to blow on the tube a series of little bulbs close to one another, and then, by heating the intervals, and blowing, to unite these little bulbs into a large one of convenient dimensions.

We have already observed, and we repeat here, that it is indispensably necessary to hold the glass *out* of the flame during the act of blowing. This is the only means of maintaining uniformity of temperature in the whole softened parts of the tube, without which it is impossible to produce bulbs with sides of equal thickness in all their extent.

When you desire to form a bulb at the extremity of a capillary tube, that is to say, of a tube which has a bore of very small diameter, such as the tubes which are commonly employed to form thermometers, it would be improper to blow it with the mouth; were you to do so, the vapour which would be introduced, having a great affinity for the glass, would soon obstruct the little canal, and present to the passage of the air a resistance which, with the tubes of smallest interior diameter, would often be insurmountable. But, even when the tubes you employ have not so very small an internal diameter, you should still take care to avoid blowing with the mouth;

because the introduction of moisture always injures fine instruments, and it is impossible to dry the interior of a capillary tube when once it has become wet. It is better to make use of a bottle of Indian rubber, which can be fixed on the open end of the tube by means of a cork with a hole bored through it. You press the bottle in the hand, taking care to hold the tube vertically with the hot part *upwards*; if you were not to take this precaution, the bulb would be turned on one side, or would exhibit the form of a pear, because, it is impossible, in this case, to give to the mass in fusion that rotatory motion which is necessary, when the tube is held horizontally, to the production of a globe perfectly spherical in its form, and with sides of equal thickness.

Whenever you blow into a tube you should keep the eye fixed on the dilating bulb, in order to be able to arrest the passage of air at the proper moment. If you were not to attend to this, you would run the risk of giving to the bulb too great an extension, by which the sides would be rendered so thin that it would be liable to be broken by the touch of the lightest bodies. This is the reason that, when you desire to obtain a lage bulb, it is necessary to thicken the extremity of the tube, or to combine many small bulbs in one, that it may possess more solidity.

In general, when you blow a bulb with the mouth, it is better to introduce the air a little at a time, forcing in the small portions very rapidly one after the other; rather than to attempt to produce the whole expansion of the bulb at once: you are then more certain of being able to arrest the blowing at the proper time.

When you desire to produce a moderate expansion, either at the extremity or in any other part of a tube, you are enabled easily to effect it by the following process, which is founded on the property possessed by all bodies, and especially by fluids, of expanding when heated; a property which characterises air in a very high degree. After having sealed one end of the tube and drawn out the other, allow it to become cold, in order that it may be quite filled with air; close the end which has been drawn out, and prevent the air within the tube from communicating with that at its exterior; then gradually heat the part which you desire to have expanded, by turning it gently in the flame of a lamp. In a short time the softened matter is acted on by the tension of the air which is enclosed and heated in the interior of the tube; the glass expands, and produces a bulb or swelling more or less extensive, according as you expose the glass to a greater or lesser degree of heat.

To blow a bulb in the middle of a tube, it is sufficient to seal it at one of its extremities, to heat the part that you wish to inflate, and, when it is at a *cherry-red* heat, to blow in the tube, which must be held horizontally and turned with both hands, of which, for the sake of greater facility, the left may be held above and the right below.

If the bulb is to be large, the matter must previously be thickened or accumulated, or, instead of that, a series of small bulbs first produced, and these subsequently blown into a single larger bulb, as we have already mentioned.

For some instruments, the tubes of which must be capillary, it is necessary to blow the bulbs separately, and then to solder them to the requisite adjuncts. The reason of this is, that it would be too difficult to produce, from a very fine tube, a bulb of sufficient size and solidity to answer the intended purpose.

You make choice of a tube which is not capillary, but of a sufficient diameter, very cylindrical, with equal sides, and tolerably substantial: it may generally be from the twentieth to the twelfth of an inch thick in the glass. You soften two zones in this tube, more or less near to each other, according to the bulk you desire to give to the bulb, and you draw out the melted part in points. The art consists in *well-centering*—that is to say, in drawing out the melted tube in such a manner that the thin parts or points shall be situated exactly in the prolongation of the axis of the little portion of the original tube remaining between them. This operation is technically termed drawing *a cylinder between two points*. You cut these points at some distance from the central or thick part, and seal one end; you next completely soften the little thick tube and expand it into a bulb, by blowing with the precautions which have already been described. You must keep the glass in continual motion, if you desire to be successful in this experiment. Much rapidity of movement, and at the same time lightness of touch, are requisite in the operation here described. It is termed *blowing a bulb between two points.*

To obtain a *round* bulb, you should hold the tube horizontally; to obtain a *flattened* bulb, you should hold it perpendicularly, with the fused extremity turned above; to obtain a *pear-shaped* bulb, you should hold the fused extremity downwards.

When you are working upon a bulb between two points, or in the middle of a tube, you should hold the tube horizontally in the ordinary manner; but you are to push the softened portion together, or to draw it out, according as you desire to produce a ridge or a prolongation.

8.—PIERCING.

You first seal the tube at one extremity, and then direct the point of the flame on the part which you desire to pierce. When the tube has acquired a *reddish-white* heat, you suddenly remove it from the flame, and forcibly blow into it. The softened portion of the tube gives way before the pressure of the air, and bursts into a hole. You expose the tube again to the flame, and border the edges of the hole.

It is scarcely necessary to observe, that, if it be a sealed extremity which you desire to pierce, it is necessary to turn the tube between the fingers while in the fire; but if, on the contrary, you desire to pierce a hole in the side of a tube, you should keep the glass in a fixed position, and direct the jet upon a single point.

If the side of the tube is thin, you may dispense with blowing. The tube is sealed and allowed to cool; then, accurately closing the open extremity with the finger, or a little wax, you expose to the jet the part which you desire to have pierced. When the glass is sufficiently softened, the air enclosed in the tube being expanded by the heat, and not finding at the softened part a sufficient resistance, bursts through the tube, and thus pierces a hole.

You may generally dispense with the sealing of the tube, by closing the ends with wax, or with the fingers.

There is still another method of performing this operation, which is very expeditious, and constantly succeeds with objects which have thin sides. You raise to a *reddish-white* heat a little cylinder of glass, of the diameter of the hole that you desire to make, and you instantly apply it to the tube or globe, to which it will strongly adhere. You allow the whole to cool, and then give the auxiliary cylinder a sharp slight knock; the little cylinder drops off, and carries with it the portion of the tube to which it had adhered. On presenting the hole to a slight degree of heat, you remove the sharpness of its edges.

When you purpose to pierce a tube laterally, for the purpose of joining to it another tube, it is always best to pierce it by blowing many times, and only a little at a time, and with that view, to soften the glass but moderately. By this means the tube preserves more thickness, and is in a better state to support the subsequent operation of soldering.

There are circumstances in which you can pierce tubes by forcibly sucking the air out of them; and this method sometimes presents advantages that can be turned to good account. Finally, the orifices which are produced by cutting off the lateral point of a tube drawn out at the side, may also be reckoned as an operation belonging to this article.

9.—BENDING.

If the tube is narrow, and the sides are pretty thick, this operation presents no difficulty. You heat the tube, but not too much, lest it become deformed; a *reddish-brown* heat is sufficient, for at that temperature it gives way to the slighest effort you make to bend it. You should, as much as possible, avoid making the bend too abrupt. For this purpose, you heat a zone of one or two inches in extent at once, by moving the tube backwards and forwards in the flame, and you take care to bend it very gradually.

But if the tube is large, or its sides are thin, and you bend it without proper precautions, the force you employ entirely destroys its cylindrical form, and the bent part exhibits nothing but a double flattening,—a canal, more or less compressed. To avoid this deformity it is necessary, first, to seal the tube at one extremity, and then, while giving it a certain curvature, to blow cautiously by the other extremity, which for convenience sake should previously be drawn out. When tubes have been deformed by bad bending, as above described, you may, by following this method, correct the fault; that is to say, upon sealing one extremity of the deformed tube, heating the flattened part, and blowing into the other extremity, you can with care reproduce the round form.

In general, that a curvature may be well made, it is necessary that the side of the tube which is to form the concave part be sufficiently softened by heat to sink of itself equally in every part during the operation, while the other side be only softened to such a degree as to enable it to give way under the force applied to bend it. On this account after having softened in a *cherry-red heat* one side of the tube, you should turn the other which is to form the exterior of the curvature, towards you, and then, exposing it to the point of the jet, you should bend the tube immediately upon its beginning to sink under the heat.

10.—SOLDERING.

If the tubes which you propose to solder are of a small diameter, pretty equal in size and have thick sides, it is is sufficient, before joining them together, to widen them equally at their extremities, by agitating a metallic rod within them.

But if they have thin sides, or are of large diameter, the bringing of their sides into juxta-position is very difficult, and the method of soldering just indicated becomes insufficient. In this case you are obliged to seal, and subsequently to pierce, the two ends which you desire to join. The disposition which this operation gives to their sides very much facilitates the soldering.

Finally, when the tubes are of a very different diameter, you must draw out the extremity of the larger, and cut it where the part drawn out corresponds in diameter to the tube which it is to be joined to.

For lateral solderings you must dispose the tubes in such a manner that the sides of the orifices which you desire to join together, coincide with each other completely.

When the holes are well prepared, you heat at the same time the two parts that are to be soldered together, and join them at the moment when they enter into fusion. You must push them slightly together, and continue to heat successively all their points of contact whereupon the two tubes soon unite perfectly. As it is almost always necessary, when you desire the soldering to be neatly done, or the joint to be imperceptible, to terminate the operation by blowing, it is proper to prepare the extreme ends of the tubes before hand. That end of the tube by which you intend to blow should be carefully drawn out, provided it be so large as to render drawing out necessary; and the other end of the tube, if large, should be closed with wax, or if small, should be sealed at the lamp. When the points of junction are perfectly softened, and completely incorporated with each other, you introduce a little air into the tube, which produces a swelling at the joint. As soon as this has taken place, you must gently pull the two ends of the joined tube in different directions, by which means the swelled portion at the joint is brought down to the size of the other parts of the tube, so that the whole surface becomes continuous. The soldering is then finished.

To solder a bulb or a cylinder between two points, to the extremity of a capillary tube, you cut and seal one of the points at a short distance from the bulb, and at the moment when this extremity is in fusion, you pierce it by blowing strongly at the other extremity. By this means the opening of the reservoir is terminated by edges very much widened, which facilitates considerably its being brought into juxtaposition with the little tube. In order that the ends of the two tubes may be well incorporated the one with the other, you should keep the soldered joint for some time in the flame, and ought to blow in the tube, push the ends together and draw them asunder, until the protuberance is no longer perceptible.

If, after having joined two tubes, it should be found that there still exists an opening too considerable to be closed by simply pushing the two tubes upon one another, you can close such an opening by means of a morsel of glass, applied by presenting the fused end of an auxiliary tube.

You should avoid soldering together two different species of glass—for example, a tube of ordinary glass with a tube of flint-glass; because these two species of glass experience a different degree of contraction upon cooling, and, if joined together while in a fused state, are so violently pulled from one another as they become cool, that the cohesion of the point of soldering is infallibly overcome, and the tube breaks. You ought also, for a similar reason, to take care not to accumulate a greater mass of glass in one place than in another.

If the first operation has not been sufficient to complete the soldering, the tube must be again presented to the flame, and again pushed together at the joint, or drawn asunder, or blown into, according as it may appear to be necessary. In all cases the soldering is not truly solid, but inasmuch as the two masses of glass are well incorporated together, and present a surface continuous in all points.

The mineralogical flame is that which is to be employed in preference to the larger flame, when you desire to effect a good joining: it is sufficient to proportion the size of the flame to the object you wish to execute.

APPENDIX.

PART IV.

PREPARATION OF METALLIC ALLOYS AND AMALGAMS.

This article is chiefly condensed from Mackenzie's "*Thousand Experiments,*" and from the third volume of Dumas' "*Sur la Chimie appliquée aux Arts.*"

When a metal combines chemically with another metal, so as to alter its properties, the compound is called an Alloy. Alloys, generally, possess properties very different from those of the metals which compose them. In some instances their specific gravity is greater: in others, they are more fusible, more ductile, and elastic; or they vary in colour or durability. An alloy, too, is often more sonorous than its component metals in a separate state.

Brass.—Put 4½ ounces of Copper into a crucible, expose it to heat in a furnace, and when perfectly fused, add an ounce and a half of Zinc. The metals will combine, forming that generally used Alloy called Brass.

Pinchbeck.—Put into a crucible five ounces of pure Copper; when it is in a state of fusion, add an ounce of Zinc. These metals combine, forming an Alloy, called Pinchbeck, not unlike Jewellers' gold: pour it into a mould of any shape. This alloy is used for inferior jewellery.

Prince's Metal.—Melt in a crucible 4 ounces of Copper, and when fused, add 2 ounces of Zinc: they will combine and form a very beautiful and useful Alloy called Prince Rupert's metal.

Bronze.—Melt in a clean crucible 7 ounces of pure Copper, when fused, throw into it 3 ounces of Zinc, and 2 ounces of Tin. These metals will combine, forming Bronze,—an alloy which, from the exactness of the impression which it takes from a mould, has, in ancient and modern times, been generally used in the formation of Busts, Medals, and Statues.

Gun-Metal.—Melt together 9 parts of Copper and one part of Tin; the compound is that used in the manufacture of cannons, swivels, &c.

Beautiful Alloy of Antimony and Copper.—Put into a clean crucible an ounce of Copper, and an ounce of Antimony; fuse them by a strong heat, and pour the alloy into a mould. The compound will be very hard, and of a beautiful violet hue. This alloy has not been yet applied to any useful purposes, but its excellent qualities, independent of its colour, entitle it to consideration.

Bell Metal.—Melt together 6 parts of Copper and 2 of Tin:—the composition will be that known by the name of Bell-Metal. These proportions are the most approved for bells throughout Europe, and in China.

Silver Coin of Britain.—Put into a crucible an ounce and seven drams of pure Silver, with one dram of Copper: they will combine by fusion. This alloy is the same as that used for silver coin at the Mint. It is harder and more durable than pure silver, and its lustre is not in the least impaired.

Gold Coin of Great Britain.—Put into a clean crucible one dram of pure Copper, and when it is in a fused state, throw in an ounce and 3 drams of pure gold. These metals will combine, forming an alloy of Gold with Copper, 22 carats fine. The goodness of this alloy depends upon the relative quantities of the metals employed; it is said to be 22 carats fine, because 22 parts of gold have been used with two of copper; or, as here directed, 11 drams of gold and one of copper, these being in the same proportion as 22 to 2. This alloy is rendered harder than pure gold, therefore not so liable to be worn away by friction. Pure gold loses very little of its colour by admixture with copper in these proportions. Jewellers' Gold always contains *one half* of copper.

Queen's Metal.—Melt together 4½ ounces of Tin, half an ounce of Bismuth, half an ounce of Antimony, and half an ounce of Lead. A very excellent alloy will be formed by using these proportions; it is called Queen's Metal, and is used for making tea-pots and other vessels, which are required to imitate silver. They retain their brilliancy to the last.

Pewter.—Melt in a crucible 3½ pounds of Tin, and when fused, throw in 8 ounces of Lead, 3 of Copper, and 1 of Zinc. This combination of metals will form an alloy of great durability and tenacity; also of considerable lustre. It is known by the name of Pewter.

Alloy for Soldering.—Put into a crucible 2 ounces of Lead, and when it is melted, throw in an ounce of Tin. This alloy is that generally known by the name of Solder. When heated by a hot iron, and applied to tinned iron with powdered resin, it acts as a cement of solder; it is also used to join leaden pipes, &c.

Useful Alloy of Gold with Platinum.—Put into a clean crucible 7 drams and a half of pure Gold, and when perfectly melted, throw in half a dram of Platinum. The two metals will combine intimately, forming an alloy rather whiter than pure gold, but remarkably *ductile* and *elastic;* it is also less perishable than pure gold or jewellers' gold; but more readily fusible than that metal.

These excellent qualities must render this alloy an object of great interest to workers in metals. For *Springs*, where steel cannot be used, it will prove exceedingly advantageous.

It is a curious circumstance, that the alloy of gold and platinum is soluble in nitric acid, which does not act on either of the metals, in a separate state. It is remarkable, too, that the alloy has very nearly the colour of platinum, even when composed of eleven parts of gold to one of the former metal.

Useful Alloy of Silver with Steel.—When 1 part of Silver and 500 parts of Steel were properly fused, a very fine button was produced. No silver appeared on its surface;

when forged, and dissected by an acid, no fibres were seen, although examined by a highly magnifying power. The specimen forged remarkably well, although very hard; it had in every respect the most favourable appearance. By a delicate test, every part of the bar shewed silver. This alloy is decidedly superior to the very best steel, and this excellence is unquestionably owing to combination with a minute portion of silver. It has been repeatedly made, and always with the same success. Various cutting tools have been made from it of the best quality.

This alloy is perhaps only inferior to that of steel with rhodium, and it may be procured at a small expence; the value of the silver, where the proportion is so small, is not worthy of consideration; it will probably be applied to many important purposes in the arts.

WOOTZ.—Pure Steel, in small pieces, was heated intensely for a long time, and formed a highly crystalline carburet. This being broken, and rubbed to powder in a mortar, was mixed with pure alumine, and the whole intensely heated in a close crucible for a considerable time. The result was a brittle alloy of a white colour, and close granular texture. When 700 grains of good Steel, and 40 of the Alumine alloy were fused together, they yielded a good malleable button, which being forged into a bar and polished, gave by the application of diluted sulphuric acid, the beautiful damask which is peculiar to Wootz, and which Wootz retains even after repeated fusions. A second specimen obtained from 500 grains of the same steel, and 67 of the alumine alloy, possessed all the appreciable characters of the best Bombay Wootz.

PRINTERS' TYPES.—Put into a crucible 5 ounces of Lead, and when it is in a state of fusion, throw in an ounce of Antimony; these metals in such proportions form the alloy of which common printing types are made. The antimony gives a hardness to the lead, without which the type would speedily be rendered useless in a printing-press.

Alloy for small Types, and Stereotype Plates.—Melt 4½ ounces of Lead, and throw into the crucible an ounce of Antimony, and half an ounce of Bismuth: these metals will combine, forming an alloy of a peculiar quality. This quality is expansion as it cools; it is therefore well suited for the formation of small printing types, (particularly when many are cast together to form Stereotype plates,) as the whole of the mould is accurately filled with the alloy; consequently there can be no blemish in the letters. But if a metal or alloy liable to *contract* in cooling were to be used, the effect of course would be very different.

The proprietors of different founderies adopt different compositions for stereotype plates. Some form an alloy of 8 parts of lead, 2 parts of antimony, and $\frac{1}{8}$ part of tin.

Amalgams.—Amalgamation is the combination of Mercury with any other metal. The compound has always been called an Amalgam, though, properly speaking, it is an alloy. The general way of combining mercury with metals is by heat. Amalgams of some metals may be made by merely triturating them with mercury in a mortar.

Put two drams of Mercury into a crucible, and heat it until a vapour be seen to arise from it; now throw into the crucible 1 dram of gold or silver, and stir them with an iron rod. When the gold or silver is known to be fused, the amalgam is formed, and should be poured into a basin of cold water; when cool, pour off the water, and collect the amalgam, which will be a yellowish silvery mass, of about the consistency of soft butter. This, after having been bruised in a mortar, or shaken in a strong phial, with repeated portions of salt and water, (till the water ceases to be fouled by it,) is fit for use, and may be kept for any length of time without injury, in a corked phial. It is of essential importance that the materials of this amalgam, and especially the mercury, should be perfectly pure, as the least portion of lead or bismuth would very materially injure the beauty of the gilding (when the amalgam is used for this purpose,) by deteriorating the colour of the gold, and filling it with black specks. On this account, no mercury should be employed but what has been distilled from the red oxide of mercury, (red precipitate,) either alone, or mixed with a little charcoal powder. When any substance is to be silvered or gilt, it must be first made very clean (copper for example), then rubbed over with the amalgam, and then exposed to a heat of 656°, when the mercury will fly off, leaving a coat of silver or gold on the copper. There are furnaces constructed for the volatilization of mercury from gilded vessels, by which the vapour of the mecury is prevented from affecting the hands or face of the operator: before this invention, gilding was a very unwholesome occupation.

AMALGAM FOR THE CUSHIONS OF ELECTRICAL MACHINES.—Melt together in a crucible 2 drams of Zinc, and one of Tin; when fused, pour them into a cold crucible, containing 5 drams of mercury. The mercury will combine with those metals, and form an ally (or amalgam, as it is called), fit to be rubbed on the cushions which press the plate or cylinder of an electrical machine. Before the amalgam is applied, it is proper to rub the cushion with a mixture of tallow and bees' wax.

ALLOY FOR VARNISHING FIGURES.—Fuse ½ an ounce of Tin, with the same quantity of Bismuth, in a crucible; when melted, add ½ an ounce of Mercury. When perfectly combined, take the mixture from the fire and cool it. This substance, mixed with the white of an egg, forms a very beautiful varnish, for plaster figures, &c.

APPLICATION OF METALLIC COATINGS OF MERCURY, SILVER, GOLD, AND TIN.

Precipitation of Mercury on Copper.—Drop a solution of the nitrate of mercury on a plate of clean copper, so that the whole surface may be equally covered. Wipe the liquid off gently, and rub the copper dry with a piece of soft leather. The plate will now be covered with a coat of metallic mercury.

Precipitation of Copper on Zinc.—Into a wine glass nearly filled with distilled water, put 10 grains of powdered sulphate of copper, and 2 drops of nitric acid; stir the whole with a glass rod, until the salt be dissolved; then immerse a rod of zinc; the copper will be immediately precipitated upon the rod in the metallic form.

Precipitation of Gold upon Iron.—If a bright or well polished iron rod be immersed in a solution of nitro-muriate of gold, the gold will be precipitated on it in the metallic state.

Precipitation of Lead on Zinc; *or, the Lead Tree.*—Put half an ounce of the super-acetate of lead in powder, into a clear glass globe, or wine decanter filled to the bottom of the neck with distilled water; add 10 drops of nitric acid, and shake the mixture well. Prepare a rod of zinc with a hammer and file, so that it may be a quarter of an inch thick, and an inch long; at the same time, form notches in each side for a thread, by which it is to be suspended, and tie the thread so, that the knot shall be uppermost, when the metal hangs quite perpendicular. When it is tied, pass the two ends of the thread through a perforation in the cork, and let them be again tied over a small splinter of wood which may pass between them and the cork. In tying the string, let the length between the cork and the zinc be such, that the precipitant (the zinc) may be at equal distances from the sides, bottom, and top, of the vessel, when immersed in it. When all things are thus prepared, place the vessel in a place where it may not be disturbed, and introduce the zinc, at the same time fitting in the cork. The metal will very soon be covered by the lead, which it precipitates from the solution, and this will continue to take place until the whole become attached to the zinc, assuming the form of a tree or bush, whose leaves and branches are laminal, or in plates of a metallic lustre.

PRECIPITATION OF TIN UPON ZINC; *or, the Tin Tree.*—Into the same, or a similar vessel to that used in the last experiment, pour distilled water as before, and put in 3 drams of muriate of tin, adding 10 drops of nitric acid, and shake the vessel until the salt be completely dissolved. Replace the zinc (which must be cleaned from the effects of the former experiment), as before, and set the whole aside to precipitate without disturbance. In a few hours the effect will be similar to the last, only that the tree of tin will have more lustre.

PRECIPITATION OF SILVER BY MERCURY; *or, the Silver Tree.*—Pour into a glass globe or decanter 4 drams of nitrate of silver dissolved in a pint or more of distilled water, and lay the vessel on the chimney piece, or in some place where it may not be disturbed. Now pour in 4 drams of mercury. In a short time the silver will be precipitated in the most beautiful arborescent form, resembling real vegetation. This has been generally termed the Arbor Dianæ, or Tree of Diana.

PRECIPITATION OF SILVER ON COPPER.—Dissolve 10 grains of the crystallized nitrate of silver in a wine-glass full of water; and immerse a clean slip or rod of copper; a beautiful metallic precipitate will immediately begin to take place upon it. The silver will be seen, as it were, to dart into existence in the crystalline form.

SILVERING COPPER, &c.—Dissolve a grain of nitrate of silver in water, and immerse in it a piece of very clean copper; the silver will be precipitated on it. When no more silver will fall down, wipe it off from the copper with a feather or a piece of paper, and after having pressed out the water, weigh 15 grains of it, to be mixed with 2 drams of super-tartrate of potass, 2 drams of muriate of soda, and 30 grains of alum. When these substances are properly combined, let them be rubbed on any clean piece of brass or copper. A white shining coat of silver will presently appear, which will bear repeated polishing with leather.

Precipitation of Copper on Silver and Iron.—If a silver spoon be immersed in a solution of sulphate of copper, both the metal and solution will remain unaltered; but if a polished iron rod also be immersed in this liquid, so that the lower ends of each may come in contact, a precipitation of metallic copper will take place on both the rod and spoon: that is, they will both be covered with a coat of copper.

Silvering Ivory.—Prepare a diluted solution of nitrate of silver, and immerse in it an ivory paper knife. When the ivory has become yellow, in that part where it is in contact with the fluid, take it out and immerse it in a glass containing distilled water, placed in a window; in a short time, by exposure to the rays of the sun, it will become intensely black.

Take it out of the water, and having wiped it dry, rub it with a piece of leather. The silver will now appear on the ivory in a metallic state. The knife will retain its silvery coat for a long time.

Reduction of Silver from the Nitrate upon Charcoal, by the action of the Sun's rays.—Immerse a thin slip of charcoal in a glass, containing a solution of nitrate of silver; place the glass in a window, and leave it undisturbed; a film of metallic silver will be deposited over the whole surface.

Method of Tinning Brass Pins.—Fill a tinned copper vessel with alternate layers of brass pins, and plates or pieces of tin. Now pour over the whole a saturated solution of super-tartrate of potass in hot water, so that the vessel may be quite full. Now place the vessel upon the fire, and let the liquid boil for 5 or 6 hours. When cold, the pins will be completely coated by the tin, which being dissolved by the salt, is precipitated on the brass.

Tin tacks are whitened in a similar manner.

Tinning Iron.—Clean with coal ashes a slip of sheet iron, so that it may possess a good lustre; and put it in a vessel containing a quart of water and one dram of sulphuric acid; let it remain in this state for a day and a night. Take it out at the end of that time, and dry it well; then grease it with a piece of tallow, and put it in a hot oven or other place. Now melt an ounce of tin in a crucible, and dip the clean slip whilst *hot* in it, taking care that the tin shall cover all parts of it. When cut in pieces by a pair of scissors, the metals will be found to have completely combined, for the whole will possess a silvery lustre.

This, on a small scale, is the mode in which sheets of iron are tinned at the manufactories. When the iron plates have been either hammered or rolled to a proper thickness, they are steeped in an acid liquor, which is produced from the fermentation of barley meal, although any other weak acid will answer the purpose; this steeping, and a subsequent scouring, cleans the surface of the iron from every speck of rust or blackness, the least particle of which would hinder the tin from adhering. After the plates have been made quite bright, they are put into an iron pot filled with melted tin; the surface of melted tin is kept covered by suet or pitch, or some fat substance, to prevent it from being oxidised; the tin presently unites itself to the iron, covering each side of every plate with a thin white coat; the plates are then taken out; and, (after undergoing some further operations, which render them more neat and saleable,) are packed up in boxes. These are every where to be met with in commerce, under the name of tin-plates though the principal part of their substance is iron.

Tinning Copper.—Clean a slip of copper from all impurities, by using a piece of flannel and whiting, and afterwards removing any dust by polishing it with leather. Next rub it over with muriate of ammonia. Then heat the slip, and immediately afterwards rub it over with a piece of tallow or pitch. Now heat it again, and rub it over with a piece of tin; this metal will immediately combine with the surface, giving it a silvery coat.

The mixture generally used for the tinning of copper vessels, consists of 3 pounds of lead, and 5 pounds of pewter; when a finer composition is required, ten parts of lead are mixed with sixteen of tin; or one part of lead with two of tin: but the proportions in which lead and tin are mixed together, even for the same kind of work, are not every where the same; different artists having different methods. Vessels tinned with pure tin, or with the best kind of pewter, (which contains no lead,) do not stain the fingers when rubbed by them; whilst those which are tinned with a composition into which lead enters as a constituent part, colour the fingers of a blackish tinge.

The common method of tinning consists in making the surface of the copper vessel quite bright, by scraping it, and by washing it with a solution of muriate of ammonia: it is then heated, and the tin, or metallic mixture designed for tinning, is melted, and poured into it; and being made to flow quickly over every part of the surface of the vessel, it incorporates with the copper, and, when cold, remains united with it. Rosin or pitch is used, to prevent the tin from being oxidised, and the copper from being scaled; either of which circumstances would hinder the sticking of the tin.

Great care should be taken with all vessels, even when well tinned; not to allow acid substances to remain in them for any length of time, because the two will become corroded thereby; and part of the copper afterwards dissolving in any future acid or salt liquor which may be put in such vessels, will render it highly poisonous.

Plating Looking Glasses.—This art is erroneously termed *Silvering*, for as will be presently seen, there is not a particle of Silver present in the whole composition.

On tin-foil, fitly disposed on a flat table mercury is to be poured, and gently rubbed with a hare's foot; it soon unites itself with the tin, which then becomes very splendid, or, as the workmen say, is *quickened;* a plate of glass is then cautiously to be slid upon the tin leaf, in such a manner as to sweep off the redundant mercury, which is not incorporated with the tin; leaden weights are then to be placed on the glass; and in a little time the quicksilvered tin-foil adheres so firmly to the glass, that the weights may be removed without any danger of its falling off. The glass thus coated is a common looking-glass. About two ounces of mercury are sufficient for covering three square feet of glass.

The success of this operation depends much on the clearness of the glass; and the least dirt or dust on its surface will prevent the adhesion of the amalgam, or alloy.

Gilding Glass and Porcelain.—Drinking, and other glasses are sometimes gilt on their edges. This is done either by an adhesive varnish, or by heat. The varnish is prepared by dissolving in boiled linseed oil, an equal weight either of copal or amber. This is to be diluted by a proper quantity of oil of turpentine, so as to be applied as thin as possible to the parts of the glass intended to be gilt. When this is done, which will be in about 24 hours, the glass is to be placed in a stove, till it is so warm as almost to burn the fingers when handled. At this temperature, the varnish will become adhesive, and a piece of leaf gold applied in the usual way will immediately stick. Sweep off the superfluous portions of the leaf; and when quite cold, it may be burnished, taking care to interpose a piece of very thin paper (India paper) between the gold and the burnisher. If the varnish is very good, this is the best method of gilding glass, as the gold is thus fixed on more evenly than in any other way: it often happens, however, when the varnish is but indifferent, that by repeated washing the gold soon wears off: on this account the practice of burning it in, is sometimes had recourse to.

For this purpose, some gold powder is ground with borax, and in this state applied to the clean surface of the glass, by a camel's pencil; when quite dry, the glass is put into a stove heated to about the temperature of an annealing oven; the gum burns off, and the borax, by vitrifying, cements the gold with great firmness to the glass; after which it may be burnished.

The gilding upon porcelain is in like manner fixed by heat and the use of borax; and this kind of ware being neither transparent nor liable to soften, and thus injure its form in a low red heat, is free from the risk and injury which the finer and more fusible kinds of glass are apt to sustain from such treatment.

APPENDIX.

PART V.

The following articles on the Analysis of minerals and mineral waters are taken from the last edition of Turner's Chemistry.

ANALYSIS OF MINERALS.

As the very extensive nature of this department of analytical chemistry renders a selection necessary, I shall confine my remarks solely to the analysis of those earthy minerals with which the beginner usually commences his labours. The most common constituents of these compounds are silica, alumina, iron, manganese, lime, magnesia, potassa, soda, and carbonic and sulphuric acids; and I shall, therefore, endeavour to give short directions for determining the quantity of each of these substances.

In attempting to separate two or more fixed principles from each other, the first object of the analytical chemist is to bring them into a state of solution. If they are soluble in water, this fluid is preferred to every other menstruum; but if not, an acid or any convenient solvent may be employed. In many instances, however, the substance to be analyzed resists the action even of the acids, and in that case the following method is adopted:—The compound is first crushed by means of a hammer or steel mortar, and is afterwards reduced to an impalpable powder in a mortar of agate; it is then intimately mixed with three, four, or more times its weight of potash, soda, baryta, or their carbonates; and, lastly, the mixture is exposed in a crucible of silver or platinum to a strong heat. During the operation, the alkali combines with one or more of the constituents of the mineral; and, consequently, its elements being disunited, it no longer resists the action of the acids.

Analysis of Marble or Carbonate of Lime.—This analysis is easily made by exposing a known quantity of marble for about half an hour to a full white heat, by which means the carbonic acid gas is entirely expelled, so that by the loss in weight the quantity of each ingredient, supposing the marble to have been pure, is at once determined. In order to ascertain that the whole loss is owing to the escape of carbonic acid, the quantity of this gas may be determined by a comparative analysis. Into a small flask containing hydrochloric acid diluted with two or three parts of water, a known quantity of marble is gradually added, the flask being inclined to one side, in order to prevent the fluid from being flung out of the vessel during the effervescence. The diminution in weight experienced by the flask and its contents, indicates the quantity of carbonic acid which has been expelled.

Should the carbonate suffer a greater loss in the fire than when decomposed by an acid, it will most probably be found to contain water. This may be ascertained by heating a piece of it to redness in a glass tube, the sides of which will be bedewed with moisture, if water is present. Its quantity may be determined by causing the watery vapour to pass through a weighed tube filled with fragments of the chloride of calcium, by which the moisture is absorbed.

Separation of Lime and Magnesia.—The more common kinds of carbonate of lime frequently contain traces of siliceous aluminous earths, in consequence of which they are not completely dissolved in dilute hydro-chloric acid. A very frequent source of impurity is carbonate of magnesia, which is often present in such quantity that it forms a peculiar compound called *magnesian limestone.* The analysis of this substance, so far as respects carbonic acid, is the same as that of marble. The separation of the two earths may be conveniently effected in the following manner. The solution of the mineral in muriatic acid is evaporated to perfect dryness in a flat dish or *capsule* of porcelain, and after redissolving the residuum in a moderate quantity of distilled water, a solution of oxalate of ammonia is added as long as a precipitate ensues. The oxalate of lime is then allowed to subside, collected on a filter, converted into quicklime by a white heat and weighed; or the oxalate may be decomposed by a red heat, and after moistening the resulting carbonate with a strong solution of carbonate of ammonia, in order to supply any particles of quicklime with carbonic acid, it should be dried, heated to low redness, and regarded as pure carbonate of lime. To the filtered liquid, containing the magnesia, a mixture of pure ammonia and phosphate of soda is added, when the magnesia in the form of the ammonia co-phosphate is precipitated. Of this precipitate, heated to redness, 100 parts, according to Stromeyer, correspond to 37 of pure magnesia.

The precipitation of magnesia by means of phosphoric acid and ammonia, though extremely accurate when properly performed, requires several precautions. The liquid should be cold, and either neutral or alkaline. The precipitate is dissolved with great ease by most of the acids; and Stromeyer has remarked, that some of it is held in solution by carbonic acid whether free or in union with an alkali. The absence of carbonic acid should therefore always be insured, prior to the precipitation, by heating the solution to 212°, acidulating at the same time by hydro-chloric acid, should an alkaline carbonate be present. Berzelius has also observed, that in washing the ammoniaco-magnesian phosphate on a filter, a portion of the salt is dissolved as soon as the saline matter of the solution is nearly all removed; that is to say, it is dissolved by pure water. Hence the edulcoration should be completed by water, which is rendered slightly saline by hydrochlorate of ammonia.

Earthy Sulphates.—The most abundant of the earthy sulphates is that of lime, the analysis of which is easily effected. By boiling it for fifteen or twenty minutes with a solution of twice its weight of carbonate of soda, double decomposition ensues; and the carbonate of lime, after being collected on a filter and washed with hot water, is either heated to low redness to expel the water, and weighed, or at once reduced to quicklime by a white heat. Of the dry carbonate, fifty parts correspond to twenty-eight of lime. The alkaline solution is acidulated with hydro-chloric acid, and the sulphuric acid thrown down by chloride of barium. From the sulphate of baryta, collected and dried at a red heat, the quantity of acid may easily be estimated.

The method of analyzing the sulphate of strontia and baryta is somewhat different. As these salts are difficult of decomposition in the moist way, the following process is adopted. The sulphate, in fine powder, is mixed with three times its weight of carbonate of soda, and the mixture is heated to redness in a platinum crucible for the space of an hour. The ignited mass is then digested in hot water, and the insoluble earthy carbonate collected on a filter. The other parts of the process are the same as the foregoing.

Mode of analyzing Compounds of Silica, Alumina, and Iron.—Minerals, thus constituted, are decomposed by an alkaline carbonate, at a red heat, in the same manner as sulphate of baryta. The mixture is afterwards digested in dilute hydrochloric acid, by which means all the ingredients of the mineral, if the decomposition is complete, are dissolved. The solution is next evaporated to dryness, the heat being carefully regulated towards the close of the process, in order to prevent any of the chloride of iron, the volatility of which is considerable, from being dissipated in vapour. By this operation, the silica, though previously held in solution by the acid, is entirely deprived of its solubility; so that on digesting the dry mass in water acidulated with hydro-chloric acid, the alumina and iron are taken up, and the silica is left in a state of purity. The siliceous earth, after subsiding, is collected on a filter, carefully edulcorated, heated to redness, and weighed.

To the clear liquid, containing peroxide of iron and alumina, a solution of pure potash is added in moderate excess; so as not only to throw down those oxides, but to dissolve the alumina. The peroxide of iron is then collected on a filter, edulcorated carefully until the washings cease to have an alkaline re-action, and is well dried on a sand-bath. Of this hydrated peroxide, forty-nine parts contain forty of an hydrous peroxide of iron. But the most accurate mode of determining its quantity is by expelling the water by a red heat. This operation, however, should be done with care; since any adhering particles of paper, or other combustible matter, would bring the iron into the state of black oxide, a change which is known to have occurred by the iron being attracted by a magnet.

To procure the alumina, the liquid in which it is dissolved is boiled with hydro-chlorate of ammonia, when chloride of potassium is formed, the volatile alkali is dissipated in vapour, and the alumina subsides. As soon as the solution is thus rendered neutral, the hydrous alumina is collected on a filter dried by exposure to a white heat, and quickly weighed after removal from the fire.

Separation of Iron and Manganese.—A compound of these metals or their oxides may be dissolved in hydro-chloric acid. If the iron is in a large proportion compared with the manganese, the following process may be adopted with advantage. To the cold solution considerably diluted with water, and acidulated with hydro-chloric acid, carbonate of soda is gradually added, and the liquid is briskly stirred with a glass rod during the effervescence, in order that it may become highly charged with carbonicacid. By neutralizing the solution in this manner, it at length attains a point at which the peroxide of iron is entirely deposited, leaving the liquid colourless; while the manganese, by aid of the free carbonic acid, is kept in solution. The iron, after subsiding, is collected on a filter, and its quantity determined in the usual manner. The filtered liquid is then boiled with an excess of carbonate of soda; and the precipitated carbonate of manganese is collected, heated to full redness in an open crucible, by which it is converted into the red oxide, and weighed. This method is one of some delicacy; but in skilful hands it affords a very accurate result. It may also be employed for separating iron from magnesia and lime, as well as from manganese.

But if the proportion of iron is small compared with that of manganese, the best mode of separating it is by succinate of ammonia or soda, prepared by neutralizing a solution of succinic acid with either of those alkalies. That this process should succeed, it is necessary that the iron be wholly in the state of peroxide, that the solution be exactly neutral, which may easily be insured by the cautious use of ammonia, and that the reddish brown-coloured succinate of peroxide of iron be washed with cold water. Of this succinate, well dried at a temperature of 212°, 90 parts correspond to 40 of the peroxide. From the filtered liquid the manganese may be precipitated at a boiling temperature by carbonate of soda, and its quantity determined in the way above mentioned. The benzoate may be substituted for succinate of ammonia in the preceding process.

It may be stated as a general rule, that whenever it is intended to precipitate iron by means of the alkalies, the succinates, or benzoates, it is essential that this metal be in the maximum of oxidation. It is easily brought into this state by digestion with a little nitric acid.

Separation of Manganese from Lime and Magnesia.—If the quantity of the former be proportionally small, it is precipitated as a sulphuret by hydro-sulphate of ammonia or sulphuret of potassium. The sulphuret is then dissolved in hydro-chloric acid, and the manganese thrown down as usual by means of an alkali. But if the manganese be the chief ingredient, the best method is to precipitate it at once, together with the two earths, by a fixed alkaline carbonate at a boiling temperature. The precipitate, after being exposed to a low red heat and weighed, is put into cold water acidulated with a drop or two of nitric acid, when the lime and magnesia will be slowly dissolved with effervescence. Should a trace of the manganese be likewise taken up, it may easily be thrown down by hydro-sulphate of ammonia.

Stromeyer has recommended a very elegant, and still better process for removing small quantities of manganese from lime and magnesia. The solution is acidulated with nitric or hydrochloric acid, bicarbonate of soda is gradually added in very slight excess, stirring after each addition, that the liquid may be charged with carbonic acid, and a solution of chlorine, or a current of the gas, is introduced. The protoxide of manganese is converted by the chlorine into the insoluble hydrated peroxide, while any traces of lime or magnesia, which might otherwise fall, are retained in solution by means of carbonic acid. A solution of chloride of soda or lime is in fact our most delicate test for small quantities of manganese.

Mode of analyzing an Earthy Mineral containing Silica, Iron, Alumina, Manganese, Lime, and Magnesia.—The mineral, reduced to fine powder, is ignited with three or four times its weight of carbonate of potassa or soda, the mass is taken up in dilute hydro-chloric acid, and the silica separated in the way already described. To the solution, thus freed from silica and duly acidulated, carbonate of soda, or still better the bicarbonate, is gradually added, so as to charge the liquid with carbonic acid, as in the analysis of iron and manganese. In this manner the iron and alumina are alone precipitated, substances which may be separated from each other by means of pure potassa. The manganese, lime, and magnesia may then be determined by the processes above described.

Analysis of Minerals containing a fixed Alkali.—When the object is to determine the quantity of fixed alkali, such as potassa or soda, it is of course necessary to abstain from the employment of these re-agents in the analysis itself; and the beginner, will do well to devote his attention to the alkaline ingredients only. On this supposition he will proceed in the following manner. The mineral is reduced to a very fine powder, mixed intimately with six times its weight of artificial carbonate of baryta, and exposed for an hour to a white heat. The ignited mass is dissolved in dilute hydrochloric acid, and the solution evaporated to perfect dryness. The soluble parts are taken up in hot water; an excess of carbonate of ammonia is added; and the insoluble matters, consisting of silica, carbonate of baryta, and all the constituents of the mineral, excepting the fixed alkali, are collected on a filter. The clear solution is evaporated to dryness in a porcelain capsule, and the dry mass is heated to redness in a crucible of platinum, in order to expel the salts of ammonia. The residue is chloride of potassium or sodium.

In this analysis, it generally happens that traces of manganese, and sometimes of iron, escape precipitation in the first part of the process; and, in that case, they should be thrown down by hydro-sulphate of ammonia. If neither lime nor magnesia is present, the alumina, iron, and manganese may be separated by pure ammonia, and the baryta subsequently removed by the carbonate of that alkali. By this method the carbonate of baryta is recovered in a pure state, and may be reserved for another analysis. The baryta may also be thrown down as a sulphate by sulphuric acid, in which case the soda or potassa is procured in combination with that acid; but this mode is objectionable, because the sulphate of baryta is very apt to retain small quantities of sulphate of potassa.

The analysis is attended with considerable inconvenience when magnesia happens to be present; because this earth is not completely precipitated either by ammonia or its carbonate, and therefore some of it remains with the fixed alkali. The best mode with which I am acquainted, is to precipitate the magnesia by phosphate of ammonia; subsequently separating from the filtered solution the excess of phosphoric acid by acetate of lead, and that of lead by hydro-sulphuric acid. The acetate of the alkali is then brought to dryness, ignited, and by the addition of sulphate of ammonia converted into a sulphate.

In the preceding account, several operations have been alluded to, which from their importance, deserve more particular mention. The process of filtering, for example, is one on which the success of analysis materially depends. Filtration is effected by means of a glass funnel into which a filter of nearly the same size and form, made of white bibulous paper, is inserted. For researches of delicacy, the filter, before being used, is macerated for a day or two in water acidulated with nitric acid, in order to dissolve lime and other substances contained in common paper, and it is afterwards washed with hot water till every trace of acid is removed. It is next dried at 212°, or any fixed temperature insufficient to decompose it, and then carefully weighed, the weight being marked upon it with a pencil. As dry paper absorbs hygrometric moisture rapidly from the atmosphere, the filter, while being weighed, should be inclosed in a light box made for the purpose. When a precipitate is collected on a filter, it is washed with pure water until every trace of the original liquid is removed. It is subsequently dried and weighed as before, and the weight of the paper subtracted from the combined weight of the filter and precipitate. The trouble of weighing the filter may sometimes be dispensed with. Some substances, such as silica, alumina, and lime, which are not decomposed when heated with combustible matter, may be put into a crucible while yet contained in the filter, the paper being set on fire before it is placed in the furnace. In these instances, the ash from the paper, the average weight of which is determined by previous experiments, must be subtracted from the weight of the heated mass.

ANALYSIS OF MINERAL WATERS.

Rain water collected in clean vessels in the country, or freshly fallen snow when melted, affords the purest kind of water which can be procured without having recourse to distillation. The water obtained from these sources, however, is not absolutely pure, but contains a portion of carbonic acid and air, absorbed from the atmosphere. It is remarkable that this air is very rich in oxygen. That procured from snow water by boiling was found by Gay Lussac and Humboldt to contain 34·8, and that from rain water 32 per cent. of oxygen gas. From the powerfully solvent properties of water this fluid no sooner reaches the ground and percolates through the soil, than it dissolves some of the substances which it meets with in its passage. Under common circumstances it takes up so small a quantity of foreign matter, that its sensible properties are not materially affected, and in this state it gives rise to *spring*, *well*, and *river* water. Sometimes, on the contrary, it becomes so strongly impregnated with saline and other substances, that it acquires a peculiar flavour, and is thus rendered unfit for domestic uses. It is then known by the name of *mineral water*.

The composition of spring water is dependent on the nature of the soil through which it flows. If it has filtered through primitive strata, such as quartz rock, granite, and the like, it is in general very pure; but if it meets with limestone or gypsum in its passage, a portion of these salts is dissolved, and communicates the property called *hardness*. Hard water is characterized by decomposing soap, the lime of the former yielding an insoluble compound with the margaric and oleic acid of the latter. If this defect is owing to the presence of carbonate of lime, it is easily remedied by boiling, when free carbonic acid is expelled, and the insoluble carbonate of lime subsides. If sulphate of lime is present, the addition of a little carbonate of soda, by precipitating the lime converts the hard into soft water. Besides these ingredients, the chlorides of calcium and sodium are frequently contained in spring water,

Spring water, in consequence of its saline impregnation, is frequently unfit for chemical purposes, and on these occasions distilled water is employed. Distillation may be performed on a small scale by means of a retort, in the body of which water is made to boil, while the condensed vapour is received in a glass flask, called a *recipient*, which is adapted to its beak or open extremity. This process is more conveniently conducted, however, by means of a still.

The different kinds of mineral water may be conveniently arranged for the purpose of description in the six divisions of acidulous, alkaline, chalybeate, sulphurous, saline, and silicious springs.

1. Acidulous springs, of which those of Seltzer, Spa, Pyrmont, and Carlsbad are the most celebrated, commonly owe their acidity to the presence of free carbonic acid, in consequence of the escape of which they sparkle when poured from one vessel into another. Such carbonated waters communicate a red tint to litmus paper before, but not after being boiled, and the redness disappears on exposure to the air. Mixed with a sufficient quantity of lime-water, they become turbid from the deposition of carbonate of lime. They frequently contain carbonate of lime, magnesia, and protoxide of iron, in consequence of the facility with which these salts are dissolved by water charged with carbonic acid.

The best mode of determining the quantity of carbonic acid is by heating a portion of the water in a flask, and receiving the carbonic acid, by means of a bent tube, in a graduated jar filled with mercury.

2. Alkaline waters are such as contain a free or carbonated alkali, and consequently, either in their natural state or when concentrated by evaporation, possess an alkaline re-action.

These springs are rare. The best instance hitherto met with is in water collected at the Furnas, St. Michael's, Azores, and sent to the Royal Society of Edinburgh by Lord Napier. These springs contain carbonate of soda and carbonic acid, and are almost entirely free from earthy substances. Of five different kinds of these waters examined, the greater part also contained protoxide of iron, hydro-sulphuric acid, and chloride of sodium.

3. Chalybeate waters are characterized by a strong styptic inky taste, and by striking a black colour with the infusion of gall-nuts. The iron is sometimes combined with hydro-chloric or sulphuric acid; but most frequently it is in the form of protocarbonate, held in solution by free carbonic acid. On exposure to the air, the protoxide is oxidized, and the hydrated peroxide subsides, causing the ochreous deposit so commonly observed in the vicinity of chalybeate springs.

To ascertain the quantity of iron contained in a mineral water, a known weight of it is concentrated by evaporation, and the iron is brought to the state of peroxide by means of nitric acid. The peroxide is then precipitated by an alkali and weighed; and if lime and magnesia are present, it may be separated from those earths by the process described in the last section.

Chalybeate waters are by no means uncommon; but the most noted in Britain are those of Tunbridge, Cheltenham, and Brighton. The Bath water also contains a small quantity of iron.

4. Sulphurous waters, of which the springs of Aix-la. Chapelle, Harrowgate, and Moffat afford examples, contain hydro-sulphuric acid, and are easily recognised by their odour, and by causing a brown precipitate with a salt of lead or silver. The gas is readily expelled by boiling, and its quantity may be inferred by transmitting it through a solution of acetate of oxide of lead, and weighing the sulphuret which is generated.

5. Those mineral springs are called saline, the character of which is caused by saline compounds. The salts which are most frequently contained in these waters are the sulphates and carbonates of lime, magnesia, and soda, and the chlorides of calcium, magnesium, and sodium. Potassa sometimes exists in them, and Berzelius has found lithia in the spring of Carlsbad. It has lately been discovered that the presence of hydriodic acid in small quantity is not unfrequent. As examples of saline water, may be enumerated the springs of

Epsom, Cheltenham, Bath, Bristol, Barèges, Buxton, Pitcaithly, and Toeplitz.

The first object in examining a saline spring, is to determine the nature of its ingredients. Hydro-chloric acid is detected by nitrate of oxide of silver, and sulphuric acid by chloride of barium; and if an alkaline carbonate be present, the precipitate occasioned by either of these tests will contain a carbonate of oxide of silver or baryta. The presence of lime and magnesia may be discovered, the former by oxalate of ammonia, and the latter by phosphate of ammonia. Potassa is known by the action of chloride of platinum. To detect soda, the water should be evaporated to dryness, the deliquescent salts removed by alcohol, and the matter insoluble, in that menstruum taken up by a small quantity of water, and be allowed to crystallize by spontaneous evaporation. The salt of soda may then be recognized by the rich yellow colour it communicates to flame. If the presence of hydriodic acid be suspected, the solution is brought to dryness, the soluble parts dissolved in two or three drachms of a cold solution of starch, and strong sulphuric acid gradually added.

Having thus ascertained the nature of the saline ingredients, their quantity may be determined by evaporating a pint of water to dryness, heating to low redness, and weighing the residue. In order to make an exact analysis, a given quantity of the mineral water is concentrated in an evaporating basin as far as can be done without causing either precipitation or crystallization, and the residual liquid is divided into two equal parts. From one portion the sulphuric and carbonic acids are thrown down by nitrate of baryta, and after collecting the precipitate on a filter, the hydro-chloric acid is precipitated by nitrate of oxide of silver. The mixed sulphate and carbonate is exposed to a low red heat, and weighed; and the latter is then dissolved by dilute hydro-chloric acid, and its quantity determined by weighing the sulphate. The chloride of silver, of which 143·42 parts correspond to 36·42 of hydro-chloric acid, is fused in a platinum spoon or crucible, in order to render it quite free from moisture. To the other half of the concentrated mineral water, oxalate of ammonia is added for the purpose of precipitating the lime; and the magnesia is afterwards thrown down as the ammoniaco-phosphate, by means of ammonia, and phosphoric acid. Having thus determined the weight of each of the fixed ingredients excepting the soda, the loss of course gives the quantity of that alkali; or it may be procured in a separate state by the process described in the foregoing section.

The individual constituents of the water being known, it remains to determine the state in which they were originally combined. In a mineral water containing sulphuric and hydro-chloric acids, lime, and soda, it is obvious that three cases are possible. The liquid may contain sulphate of lime and chloride of sodium, or chloride of calcium and sulphate of soda; or each acid may be distributed between both the bases. It was at one time supposed that the lime must be in combination with sulphuric acid, because the sulphate of that earth is left when the water is evaporated to dryness. This, however, by no means follows. In whatever state the lime may exist in the original spring, gypsum will be generated as soon as the concentration reaches that degree at which sulphate of lime cannot be held in solution. The late Dr. Murray, who treated this question with much sagacity, observes that some mineral waters, which contain the four principles above mentioned, possess higher medicinal virtues than can be justly ascribed to the presence of sulphate of lime. He advances the opinion that alkaline bases are united in mineral waters with those acids with which they form the most soluble compounds, and that the insoluble salts obtained by evaporation are merely products. He therefore proposes to arrange the substances determined by analysis according to this supposition. (Edin. Phil. Trans. vii.) To this practice there is no objection; but it is probable that each acid is rather distributed between several bases, than combined exclusively with either.

Sea water may be regarded as one of the saline mineral waters. Its taste is disagreeably bitter and saline, and its fixed constituents amount to about three per cent. Its specific gravity varies from 1.0269 to 1.0285; and it freezes at about 28·5° F. According to the analysis of Dr. Murray, 10,000 parts of water from the Frith of Forth contains 220·01 parts of common salt, 33·16 of sulphate of soda, 42·08 of muriate of magnesia, and 7·84 of muriate of lime. Wollaston detected potassa in sea water, which likewise contains small quantities of hydriodic and hydrobromic acids.

The water of the Dead Sea has a far stronger saline impregnation than sea water, containing one-fourth of its weight of solid matter. It has a peculiarly bitter, saline, and pungent taste, and its specific gravity is 1·211. According to the analysis of Marcet, 100 parts of it are composed of muriate of magnesia 10·246, muriate of soda 10·36, muriate of lime 3·92, and sulphate of lime 0·054. In the river Jordan, which flows into the Dead Sea, Marcet discovered the same principles as in the lake itself.

6. Siliceous waters are very rare, and in those hitherto discovered the silica appears to have been dissolved by means of soda. The most remarkable of these are the boiling springs of the Geyser and Rykum in Iceland, a gallon of which, according to the analysis of Black, contains the following substances: (Edinburgh Philos. Trans. iii. 95.)

	Geyser.	Rykum.
Soda,	5·56	3.0
Alumina,	2·80	0.29
Silica,	31·50	21·83
Muriate of Soda,	14·42	16.96
Sulphate of Soda,	8·57	7·53

The hot springs of Pinnarkún and Lúrgútha in India are analogous to the foregoing. A gallon of the water yields about 24 grains of solid matter; and the saline contents, sent to Dr. Brewster by Mr. P. Breton, was found to contain 21·5 per cent. of silica, 19 of chloride of sodium, 19 of sulphate of soda, 19 of carbonate of soda, pure soda 5, and 15·5 of water. (Edinburgh Journal of Science, No. xvii. p. 97.)

It is remarkable that nitrogen gas very generally occurs in hot springs. It was found by Longchamp in various hot springs of France, and a similar observation has been made by Dr. Daubeny. Its probable source is clearly referable to atmospheric air contained in water, which air has been deprived of its oxygen by chemical changes in the interior of the earth.

CHEMICAL EQUIVALENTS OF ELEMENTARY SUBSTANCES.

Elements.	Equivalents.	Elements.	Equivalents.	Elements.	Equivalents.
Aluminium,	13·7	Iodine,	126·3	Rhodium,	52·2
Antimony,	64·6	Iridium,	98·8	Selenium,	39.6
Arsenic,	37·7	Iron,	28	Silicium,	7·5
Barium,	68·7	Lead,	103·6	Silver,	108
Boron,	10·9	Lithium,	10	Sodium,	23.3
Bromine,	78·4	Magnesium,	12·7	Strontium,	43·8
Cadmium,	55·8	Manganese,	27.7	Sulphur,	16·1
Calcium,	20·5	Mercury,	202	Tellurium,	32·3
Carbon,	6·12	Molybdenum,	47·96	Thorium,	59·6
Cerium,	46	Nickel,	29·5	Tin,	58 9
Chlorine,	35·42	Nitrogen,	14·15	Titanium,	24·3
Chromium,	28	Osmium,	99·7	Tungsten,	94·8
Cobalt,	29·5	Oxygen,	8	Vanadium,	68·6
Copper,	31·6	Palladium,	53·3	Uranium,	217
Fluorine,	18·68	Phosphorus,	15·7	Yttrium,	32·2
Glucinium,	17·7	Platinum,	98·8	Zinc,	32 3
Gold,	199·2	Potassium,	39·15	Zirconium,	33.7
Hydrogen,	1				

Turner's Elements of Chemistry, 5th Edition.

DR. TURNER'S CLASSIFICATION OF SALTS.

Dr. Turner has grouped together all saline compounds which have a certain similarity of composition into one great class of *salts*, which is divided into the four following orders :—

Order I. The oxy-salts. This order includes no salt the acid or base of which is not an oxidized body.

Order II. The hydro-salts. This order includes no salt the acid or base of which does not contain hydrogen.

Order III. The sulphur-salts. This order includes no salt the electro-positive or negative ingredient of which is not a sulphuret.

Order IV. The haloid-salts. This order includes no salt the electro-positive or negative ingredient of which is not haloidal.

The two last classes require some explanatory remarks.

The notion of a salt has of late been much extended. Chemists have long known that metallic sulphurets occasionally combine together, and constitute what is called a *double sulphuret.* In these compounds Berzelius, whose labours have greatly added to their number, has traced an exact analogy with the salts, and applied to them the name of *sulphur-salts.* The simple sulphurets by the union of which a sulphur-salt is formed, are bi-elementary compounds, strictly analogous in their constitution to acids and alkaline bases, and which like them are capable of assuming opposite electric energies in relation to each other.

The compounds which Berzelius has enumerated as sulphur-acids, are the sulphurets of arsenic, antimony, tungsten, molybdenum, tellurium, tin, and gold. To these he has added the sulphurets of several other substances not metallic, such as sulphuret of selenium, bi-sulphuret of carbon, and the hydro-sulphuric and hydro-sulphocyanic acids.

A fourth order of salts has been formed by Berzelius, comprising for the most bi-elementry compounds, which consist of a metal on the one hand, and of chlorine, iodine, bromine, fluorine, and the radicles of the hydracids on the other. He has applied to them the name of *haloid-salts* (from άλς sea-salt, and εἶδος form), because in constitution they are analogous to sea-salt. The whole series of the metallic chlorides, iodides, bromides, and fluorides, such as chloride of sodium, iodide of potassium, and fluorspar, as well as the cyanurets, sulpho-cyanurets, and ferro-cyanurets, are included in his list of haloid-salts.

SPECIFIC GRAVITIES.

RULES FOR FINDING THE SPECIFIC GRAVITIES OF SOLIDS AND LIQUIDS.

1st. Distilled water is the standard, and its specific gravity is called 1.

2nd. To find the specific gravities of a solid heavier than water, *first* weigh the solid in air, then in water by the Hydrostatic Balance (see the Plate). The difference in weight is the weight of a quantity of water equal in bulk to the solid under examination. As the weight of the water equal in bulk to the solid is to the weight of the solid in air, so is the specific gravity of water to the specific gravity of the solid.

Example.

If the solid weigh 100 grains in air and 60 grains in water, the difference 40 is the weight of an equal bulk of water: then as 40 is to 100, 1 is to 2.50.

3rd. If the solid be lighter than water, as cork or wood for instance, attach to the light solid by a slender thread another body of such weight that when tied together they shall sink in water. The weight of the *heavier solid* in water must be previously known, and also that of *each* of the solids in air. Then weigh them together in water, note the weights, and from the difference between their weight in water and their weight in air, subtract the difference between the weight of the heavy solid in air and its weight in water. The remainder will show the weight of a quantity of water equal in bulk to the light substance.

Example.

If the weight in air of the light solid be 10, and of the heavy solid 20, and if the weight of the heavy solid in water be 18, and the two together 7, then

From their weight in air,............	20 + 10 = 30
Subtract their weight in water,....	7
	23

From this subtract the difference
between the weight of the heavy
solid in water and in air,...... 20 — 18 = 2

The remainder 21 denotes the weight of a quantity of water equal in bulk to the light solid : as 21 then is to 10 (the weight of the light solid in air) so is *one* to 0,47619, the specific gravity of the light solid.

ANOTHER MODE WITHOUT A HYDROSTATIC BALANCE.

Weigh the solid in air, and then put it into a vessel full of water, the weight of which with the water is known: the solid will displace a bulk of water equal to its own. Wipe the vessel dry, carefully replace it in the scale, and place in the opposite pan its weight in air. The difference between the present and former weight of the vessel is the weight of a quantity of water equal in bulk to the immersed solid, and the same rule of proportion as before gives the specific gravity.

TO FIND THE SPECIFIC GRAVITY OF A SOLID BODY SOLUBLE IN WATER.

Some other fluid, such as oil, alcohol, or ether, of known specific gravity, must be used. Consider this fluid the standard of comparison, and find the specific gravity of the solid compared with the oil, ether, alcohol, &c.

Then by simple proportion reduce the product to the standard of water.

Thus, if the specific gravity of the fluid used be 1, 2, and, compared with it, the specific gravity of the solid be 1.8; then, as 1.2, is to 1.8, so is 1 to 1,5.

TO FIND THE SPECIFIC GRAVITY OF A LIQUID.

Take a bottle of known weight, fill it with distilled water; weigh it carefully, pour out the water, dry the bottle, and fill it with the liquid to be examined. As the weight of the distilled water is to the weight of the liquid, so is 1 to the specific gravity required; thus, if, the distilled water be 300 grains, and the liquid 600, as 300 is to 600, so is 1 to 2.

WEIGHTS AND MEASURES.

TABLE OF APOTHECARIES' WEIGHT.

1 pound,	lb.	= 12 ounces,	=	5760 grains.
1 ounce,	ʒ	= 8 drachms,	=	480 ditto.
1 drachm,	℥	= 3 scruples,	=	60 ditto.
1 scruple,	℈	= 20 grains,	=	20 ditto.

N. B.—The apothecaries' pound and ounce contain the same number of grains as the imperial standard.

FRENCH DECIMAL WEIGHTS.

Milligramme,	=	0. 0154	Grains Troy.	
Centigramme,	=	0. 1540	,,	,,
Decigramme,	=	1. 5406	,,	,,
Gramme,	=	15. 4063	,,	,,

	lbs.	oz.	dram.		
Kilogramme, =	2	8	1	24	Grains Troy.

MEASURES OF CAPACITY.

N. B.—1 Cubic inch of pure water weighs 252.458 grains.
Imperial standard gallon contains 277.274 cubic inches.
Imperial standard gallon of distilled water weighs 70.000 grains.

APOTHECARIES' MEASURE.

1 gallon contains 231 cubic inches.
1 gallon. = 8 pints.
1 pint, = 16 ounces.
1 ounce, = 8 drachms.
1 drachm, = 60 drops or minims.

FRENCH DECIMAL MEASURE.

Litre, = 61. 02525 cubic inches.
Decilitre, 6. 10252
Centilitre, 0. 61025
Millilitre, 0. 06102

TABLE OF THE WEIGHT IN GRAINS OF VARIOUS MEASURES (APOTHECARIES') OF DIFFERENT KINDS OF FLUIDS.

	Specific gravity.	Weight in grains of			
		1 pint.	1 ounce.	1 drachm.	1 minim or drop.
Water,...	1.000	7291.66	455.72	56.96	0.947
Sulphuric Ether	1.720	5249.99	328.12	41.01	0.683
Alchohol,	0.796	5804.16	362.76	45.34	0.749
Solution of Ammonia,	0.925	6744.78	421.54	52·69	0.878
Muriatic Acid,	1.118	8152.07	509.50	63.68	1.061
Nitric Acid	1.480	10791 65	674.47	84 30	1.405
Sulphuric Acid,	1.848	13474.98	842.18	105.27	1.754

TABLE FOR THE CONVERSION OF TROY INTO TOLA OR SICCA WEIGHT.

TOLA WEIGHT.					TROY WEIGHT.			
Troy grains.	Pies.	Ans.	Tola.		Pds.	Ozs.	Dwts.	Grs.
$0\frac{1}{1}\frac{5}{6}$ =	1			Equal to				$0\frac{1}{1}\frac{5}{6}$
$11\frac{1}{4}$ =	12	1					$0\frac{1}{3}\frac{5}{2}$ or	$11\frac{1}{4}$
180 =	192	16	= 1		0 or	$0\frac{3}{8}$ or	$7\frac{1}{2}$ or	$180\frac{1}{32}$

From Muller's Table.

MISCELLANEOUS APPARATUS, &c.

LIGHTING DWELLINGS WITH GAS.

The cuts in Plate 3, explain a small gas apparatus which was constructed, and kept in use for two years, for lighting a small private house in the country, remote from gas-works, properly so called. The first attempt at this apparatus originated in the idea of placing a retort in the kitchen fire. It was soon found that the heat of an ordinary fire is insufficient to decompose the coal in the retort, so as to yield the full quantity of gas that might be expelled from it. It was also found to be very inconvenient in other respects. Recourse was now had to the erection of a small house to contain the whole apparatus. The dimensions of this building were 12 feet long by 9 feet wide and 9 feet high. The apparatus now to be described is represented in the two annexed plates. Of these, fig. 1 is a ground-plan of the house and apparatus, and fig. 2 being a prospective view of the same, in which the front wall of the house is supposed to be removed; the same letters of reference applying to both figures. A is the furnace with the retort, the latter is 15 inches long and 5 inches diameter, of cast iron, and containing a charge of 8lbs. of coal. To the upper side of the retort, and near its mouth, is joined an iron pipe B, about 1 inch in diameter, left open at top, for the purpose of cleaning off the crust of tar that forms on the inside, but while in operation the opening was closed with a wooden plug. The sloping pipe C, conveys the gas onward to the cooler or condensing vessel D. This is an oblong trough, which being kept full of cold water, and the pipe which thus conveys the gas being made to traverse the trough in the direction of the dotted lines, having at the same time an inclination towards the tar cistern. This retardation and cooling promotes the deposition of the tar and watery parts, which are borne forward by their own gravity along the slopes of the pipe, while the gas thus separated is pushed onward by the pressure from the retort, until they arrive in the cistern E. The tar and water are deposited in the bottom of this vessel, which is air-tight, except at the insertion of the bent pipe F, by which the gas is allowed to pass off towards the purifying vessel. The tar cistern is also furnished with a plug in the bottom, by which the liquids can be drawn off when they accumulate. The purifying vessel G. is composed of three inclined pipes, joined as in the figures; these are open at the top and bottom, but fitted with plugs for the convenience of filling and discharing the purifying liquor. This vessel is filled about two-thirds full of slaked lime and water brought to the consistency of thin cream, and the gas being forced through this by the pressure from the retort, is deprived of the sulphur with which it was combined. The gas now passes through the small pipe connected with the upper end of the purifier, and enters the gasometer H, from below. The gasometer is a vessel in which the gas is stored up for use. It consists of two parts, the tank and the gasholder: the tank or lower part is filled with water, and the gasholder, which is an inverted vessel, is a few inches less in diameter than the tank, to give freedom to its motions within the other. The gasholder is suspended by a rope or chain, over the pulleys attached to the beam 1, and balanced with a weight attached to the rope. The induction-pipe after leaving the purifier, descends, and entering through the bottom of the tank, rises again in the inside of the gasholder, till its extremity is an inch or two above the surface of the water. The end of the pipe is here furnished with a cup which constitutes a water-valve, allowing the gas to enter, but preventing its return. The eduction-pipe is placed in a manner similar to the last, passing through the bottom of the tank, and rising again on the outside as at K, where it is furnished with a stop-cock, and from this point the branch pipes can be carried to the apartments that are to be lighted.

From the way in which this apparatus was erected, even an approximation cannot be made to the total expence, but, exclusive of the house and the gasometer, the actual outlay amounted only to 2*l.* 7*s.* The gasholder being a cube of 3 feet, it contains 27 cubic feet of gas, at the small cost of three-halfpence. This quantity supplied the three burners for a period of six hours; hence the cost of one light for six hours is one halfpenny. The apparatus here described is exceedingly simple, and very well adapted for an establishment on a small scale; but it may be proper to remark, that, in extending it some deviation would be advisable. In the first place, the crude gas should pass the tar-cistern before entering the condenser; and if, as should always be the case, the cistern is placed at a considerable distance from the retorts, a great part of the tar is deposited during its progress thither. Again, one of the best condensing apparatus is a train of pipes, set on end, and connected at top and bottom alternately, so as to form a continuous course for the gas, and arranged so that the tar will always run towards the tar-cistern. The purifier may be constructed in a variety of ways, and these will vary also as the lime is employed in the wet or the dry state. The gasholder should be always made of sheet-iron, and of a cylindrical form. The tank may be built of stone or of cast iron, wood being the most objectionable material, from its liability to decay in such situations. When gas is used regularly, and properly attended to, a single jet-burner consumes one cubic foot per hour, emitting a light equal to three or four tallow candles of six in the pound.—*Quarterly Journal of Agriculture.*

CONSTRUCTION OF SUBSTITUTE APPARATUS.

There are few experiments described in the preceding pages which may not be performed by a zealous student or teacher, although he be unprovided with regular apparatus. Having for a long time been obliged myself to have recourse to frequent expedients for the performance of experiments, where regular instruments could not be procured, the subjoined hints derived from this experience may, I trust, be found useful to the teachers in Mofussil schools.

OPERATIONS ON THE GASES.

Gasometers, or receivers for collecting large quantities of the gases insoluble in water,—two of these made of copper or sheet-iron are described at page 24. A still cheaper, more convenient, and larger receptacle can be made with a barrel and a few feet of copper pipe on either Hope's or Pepys' plan, (see p. 25.) The barrel should be well coated with oil paint

Flexible tubes find an excellent substitute in a *hùqa* snake coated with oil paint or lac varnish.

Substitute stop cocks can be made in ten minutes by any one possessed of two small augurs or gouges of different sizes. A transverse hole is made with the larger in a piece of fine-grained wood, a second piece of wood is fitted in this hole and perforated with a smaller corresponding aperture. For experiments on the gases this simple contrivance is perfectly effectual.

The pneumatic water trough, and cheap mercury trough have been already described, (see pages 19 and 110.)—Mercury costs 4 Rs. 4 As. per factory seer. Six seers will be sufficient, and ought to be supplied to each district school.

Excellent gas jars, for collecting gases over the water or mercurial bath, are obtained from stoppered, bottles, having the bottoms cut off by the wheel used by the native bazar workmen who make the shell bangles used by Hindu women. A quart bottle of this kind, with a wooden stop-cock and a bladder fitted to it, supplies as good a transferring jar for practical purposes as could be procured from Newman's shop.

These jars are removed from place to place on a common plate with a little water. Wall shades also make capital air jars on an emergency.

With the preceding supply, a few of the Machhuyá Bazár retorts, and Gurney's oxy-hydrogen blow-pipe, all the experiments on the subjoined gases and subjects relating to them can be performed and exhibited to a class.

Oxygen.
Hydrogen.
Nitrogen.
Chlorine and Muriatic acid Gas.
Nitrous oxide.
——ic oxide.
Carbonic oxide.
———acid.
Sulphurous acid.
———ic acid.
Analysis of Atmospheric air.
Analysis and synthesis of water.
Sulphuretted Hydrogen.
Iodine and Hydriodic acid.
Phosphuretted Hydrogen.
Ammonia and several of its compounds.
Examination of Coal Gas and Oil Gas.
Cyanogen and Prussic acid.

For the production of gases, pieces of old gun-barrels, quart bottles, and the Machhuyá Bazár retorts, are quite a sufficient stock. The native earthen chauffers, or such modifications of them as any sensible person can at once contrive, are as efficient furnaces as are required for all ordinary experiments. For small experiments a spirit-lamp is the best mode of applying heat. An admirable furnace-lamp has recently been patented in Paris, of which I give a drawing. This lamp consists of a hollow ring of very soft copper *a*, capable of holding a wine-glass full of spirit. A tube the diameter of a crow quill is soldered into the ring in the manner represented by the dotted line *b*. The spirit is introduced by the screw *c*, which may be provided with a spring valve. Lastly, a small oil lamp is placed below the tube and the central opening of the ring. On lighting this lamp the spirit quickly boils and expels its vapour through the tube; the vapour takes fire and sends up a powerful jet of flame, nearly a foot long, through the central aperture of the ring. The heat is so intense that it fuses fine platinum wire, and heats a large platinum crucible and its contents to whiteness. It melts an eight-anna piece in one minute and a half, and boils a pint of water in three minutes. It enables us to seal and bend glass tubes with great facility.

A lamp of this kind, and superior, indeed, to the Paris one, was constructed by a native copper-smith for Dr. Nicholson. Similar instruments can, no doubt, be made in every town in India.

GRADUATION OF AIR JARS, TUBES, &C.

These vessels are very easily divided into cubic inches, by the following method. One cubic inch of water weighs 252 grains and a fraction, which may be neglected. Now if we weigh ten cubic inches of water, 2520, grains, and pour these into the vessel we wish to graduate, by levelling the surface of the water, which we effect by a spirit-level or plumb-line, the level of the water is marked at three equal points of the circumference by a flint or file. The space thus marked may be subdivided by compasses or by smaller weights of water.

OPERATIONS OF LIQUIDS.

Solution, filtering, testing, boiling, distilling, and evaporation in the open air, are the chief operations of this kind.

For solution any household glass vessels can be employed. For filtering liquids, if they act on metallic funnels, a substitute for glass funnels may be made in five minutes with an air jar, a waxed cork, and a piece of glass tube.

For boiling and distilling, the Ghâzipur flasks and Machhuyá Bázar retorts afford quite a sufficient apparatus.

Evaporation even of acid liquids can be conducted in the ordinary earthernware vessels. China cups and saucers answer admirably on the small scale.

If the evaporation is to be conducted at a temperature of 212°, two earthen pots should be used one over the other, water being boiled in the lower vessel.

OPERATIONS ON SOLIDS.

For the roasting of metallic ores or minerals, and for the fusion of metals the Hessian, Cornish, or black-lead crucibles are to be employed. Where these cannot be obtained, a good substitute may be made by mixing together two parts of Kolgong Khari clay and one of the Saboon Mattee from the same locality. A native potter will construct very useful crucibles with this mixture.

For the analysis of soils and earthy minerals, a platinum crucible is almost indispensable. By great care, however, in managing the heat, a silver vessel may be used.

THERMOMETERS, AIR PUMPS, &c.

Thermometers are of indispensable utility in several experiments. The subjoined description of these instruments is taken from an excellent volume on popular science, called "The Earth," lately published by Mr. Mullinger Higgins.

"Almost any substance might, under certain conditions, be employed as a thermometer. Solids and gases, however, would, from a casual consideration, appear to be best suited for this purpose, as they are more uniform in their expansion than liquids; but this deduction is not found to be practically true. The increase in magnitude, of solids, is so small, that they cannot be employed without mechanical contrivances, and the dilatation of gases is so great, that their use is attended with great practical inconvenience, when adapted to the measurement of high temperatures. Liquids are best suited for thermometers. But liquids have, in general, an irregular expansion when they approach the boiling and freezing temperature, and, therefore, that one must be chosen whose freezing and boiling points are separated by the greatest interval, at the same time comprising those temperatures which it is commonly most necessary to determine. Alcohol freezes at a very low temperature, but it is readily vaporised; the oils are vaporised at a very high temperature, but they are easily solidified. Neither of these substances, therefore, can be used for common purposes, as thermometers, though they are useful under certain circumstances. Mercury has been very generally employed, and it may be necessary to give the reader such particulars as may enable him to construct the instrument, should he wish to test the accuracy of the information which is given in this volume, or to commence a series of experiments by which the boundary of science may be extended.

"The mercury to be used for thermometrical purposes must be pure, that is, must be free from admixture with any other substance, whether solid or liquid. The best way to secure this, is, first to distil it, and it may then, if the subsequent processes be carefully attended to, be expected to give the same results, in how many instruments soever it may be employed.

"To obtain a means of observing the contraction or expansion which the liquid may suffer, is the next object. For this purpose the student may provide himself with a capillary tube that has a spherical bulb at one end, the bulb having a considerable proportion to the bulk of the whole tube. In selecting the tube, great care must be taken that its bore be uniform; for as the instrument is to be graduated, so it is necessary that any quantity of the liquid may stand at the same height in all places. To fill the tube requires a particular process, for as the bore is capillary the mercury cannot be poured into it. But if the bulb be held over a spirit-lamp, and the temperature of the contained air be raised, its expansion and the consequent escape of a portion will produce an exceedingly rarefied atmosphere. If the open end of the tube be then plunged into mercury, and the bulb be cooled, the enclosed air will lose a part of its elastic force, and the mercury will be driven into the tube by the pressure of the atmosphere. A small portion of the tube will be still occupied by air, and to expel it the instrument must be again submitted to a high temperature; and when the mercurial vapour occupies the space to the exclusion of the air, the open end of the tube must be hermetically sealed. The mercurial vapour condenses as it cools, and a tolerably perfect vacuum is formed.

The mercurial column being obtained, a scale must be attached to it. First plunge the bulb into a vessel containing melting snow, or ice, and the mercury will contract, falling to a level at which it will remain until the liquefaction is complete; and as the result is the same in all places, the point of elevation may be marked on the tube, and is called the freezing point.

Then plunge the instrument in boiling water, and the mercury will expand until it reaches a certain height, and there it will remain stationary, however intense may be the fire applied to the water; and hence we discover that there is a temperature above which it cannot be raised, and the level of the mercury may be marked as the boiling point.

The scale employed in England was invented by Fahrenheit, and is called after his name. In his day, it was supposed that the mixture of snow and salt produced the most intense cold that could be obtained by any artificial means, and he consequently took that temperature as the commencement of his scale, and marked the level of the mercury in his tube, when placed in this mixture, as 0. The interval between this and the freezing point, he divided into 32 parts or degrees; and, continuing the division, the boiling point is 212°.

"The centigrade scale is employed in France, and in this the interval between the boiling and freezing points is divided into 100°; the freezing point being 0. Reaumur's thermometer is generally used in other countries, and it differs from the centigrade in the division of the interval between the freezing and boiling points into 80 instead of 100°."

EXHAUSTION OR COMPRESSION OF AIR OR GASES.

This experiment cannot be well managed without an air-pump or exhausting and condensing syringe. I would recommend the supply of the latter instrument, with its set of stop-cocks, price 1*l.* 10*s.* to each of the district schools.

AIR-PUMP. Dr. Arnott's simple description of this instrument must make it intelligible to every student.

"A small bladder full of air may be pressed or squeezed between the hands so as to be much reduced in size, but on being relieved from the pressure it will immediately resume its former bulk.

"If a metallic tube or barrel of perfectly uniform bore *a, b,* be fitted with a moveable plug or piston *c,* which is covered with leather and oiled, so as to slide up and down without allowing the air to pass by its sides, the air between the piston and the close bottom *b* may be compressed to a hundredth or less of its usual bulk; but when allowed, will push the piston back again with the same force as it opposed to the condensation, and will recover the volume which it had before the experiment.

"The tube with its piston becomes, according to the position of its valves, either a syringe for injecting and condensing air, or a pump for exhausting or removing it from any vessel; both operations depending on the elasticity of air.

"A barrel and piston is a *condensing syringe*, when there is a flap or *valve* allowing air to pass towards the receiver but not to return. The piston, therefore, at each stroke forces what the barrel contains of air into the receiver. When the piston is lifted again after the stroke, air re-enters the barrel from the atmosphere, either through a valve in the piston, or through a small hole near the top of the barrel.—That useful contrivance, *a valve*, for whatever purpose used, and in whatever way formed, is in principle merely a moveable flap, placed on an opening, against which it is held by its weight, or by some other gentle and yielding force. Such a flap, it is evident, will allow fluid to pass only in one direction, *viz.* outwards from the opening, for any fluid tending inwards must shut the flap, and press it the closer, the greater the tendency. To convert a forcing syringe into an exhausting syringe or pump, commonly called an *air-pump*, it is only necessary to reverse the position of the valves; then, on the descent of the piston, all the air between it and the bottom, instead of entering the vessel or receiver, as in the last case, escapes by a valve in the piston itself towards the atmosphere, and, on the rising of the piston, a perfect vacuum would be left under it, but that the valve below, then opened by the elasticity of the air in the receiver, allows a part of that air to follow it. In a good air-pump there are two similar pumping barrels, as *a* and *b*, and both are worked at the same time by the reciprocating winch or handle *f*, with its pinion *e*, acting on the teeth of the piston rods *d* and *c*.

" Both pumps communicate with a tube *g h*, which at *h* rises tightly through the round plate of the machine to *i*. This flat plate is so smooth, that a glass bell or *receiver k*, with a smooth ground lip, when placed upon it, forms an air-tight joining. On working the pump, such a bell is exhausted of its air, and fitted for showing the many interesting phenomena which the air-pump can display."

BISHOP'S COLLEGE PRESS.