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CHEMISTRY FOR NURSES

A TEXTBOOK OF
CHEMISTRY FOR NURSES

BY

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PREFACE

The science of chemistry enters into every phase of everyday life. Whether it be on the battle front where the chief aim is the wholesale destruction of human life, or at the rear in the hospital tent where it is the loving duty of the nurse to save life and woo back the wasting strength, chemistry is a potent factor. No day of our lives, whether we be the humble laborer, or the exalted magistrate who must direct the destiny of millions, can be spent without a knowledge of chemistry on the part of *some one* contributing to our safety and welfare. This little book has been prepared, therefore, with the idea of more fully equipping those whose angelic visitations and watchful care must inevitably wield an ever increasing influence upon unfortunate humanity.

The book is very simply written so that all may understand. It begins with the most familiar substances of life and leads up to those not so well known. The author has aimed at all times to avoid the technical: chemical theory has been introduced when such would add greatly to the understanding of the phenomena at hand: at other times it has been omitted. The author has aimed at all times to be scientific and truthful. The practical phases of chemistry are everywhere remembered and emphasized, especially those that concern the great mass of humanity. Those substances which by their applications become our daily servitors, and those which, on the contrary, would threaten and endanger life, have been introduced and studied carefully. A variety of tables has been added near the end of the book as an appendix. The author feels that these will be both valuable and helpful in many ways, as they give, in a concise form, information often needed quickly.

No apology is made for the fact that the text is considerably larger than most of those offered up to this time. The responsibilities of the nurse are so great and the opportunities for the alleviation of suffering are so abundant that a wide knowledge of the Queen of Sciences can never come amiss. It is hoped that this book may be found a source of real help and inspiration.

Fredus N. Peters.

Kansas City, Mo.

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CHEMISTRY FOR NURSES

CHAPTER I

INTRODUCTION

Outline.—

1. Matter, Old Theories of.
2. Transmutation of Matter.
3. False Methods of Reasoning—
   Aristotle, Geber, Paracelsus.
4. Robert Boyle's theories.
5. Elements.
6. Compounds.
   (a) Method of Naming.
   (b) Parts of Compounds.
   (c) Chemical Affinity, What?
7. Mixtures.
8. Chemical Union, What?
9. Chemical Change.
   (a) Additive.
   (b) Simple Decomposition.
   (c) Metathesis or Double Decomposition.

Exercises for Review.

1. **Some Old Ideas About Matter.**—From very early times, certain philosophers have regarded earth, air, fire, and water as the four fundamental or primary substances from which everything we know can be made. Not merely did they believe these four the basis of everything; but, more than this, they felt sure it was possible to change one or more into another. For example, when

a vessel of water is heated upon a stove or allowed to stand in the sun, the water disappears. We say it evaporates: they thought that it had been changed by the heat into air, or in other words, that heat added to water produces air.

Again, when a tumbler of ice water is left sitting in a warm room, in a short time drops of moisture appear upon the outside of the glass. We say that the moisture in the air has been condensed upon the cold surface; the old philosophers thought as heat had converted the water into air, so cold had changed the air back into water.

When pure water is evaporated, it leaves no residue; but impure or hard water under like conditions leaves more or less of a sediment upon the walls of the containing vessel. This appears as "lime" or "scale" upon the inside of the tea kettle in the kitchen, or in the hot-water coil in the furnace, or in the boiler of the steam engine. We understand what this is; but the ancient philosophers thought that while by heat the greater part of water changes into *air* a small portion becomes *earth*. So according to their reasoning there was a very close relation existing among the four primary substances, and it was no difficult matter to change one into another.

2. **Other Observations.**—The old philosophers had observed other facts also which led them to believe in the transmutation of one substance into another. For example, their picks and other steel tools, left standing for a few days in the water which gradually seeped into their copper mines, always became coated with a thin layer of copper. This may be illustrated by immersing a bright nail in a dilute solution of copper sulphate for a few minutes. They had no true knowledge of what

was happening, but believed the iron was being changed into copper. They knew also, that by fusing copper with a certain mineral, called cadmia, which we now know contains zinc, they could obtain a substance we call brass, which may closely resemble gold. They knew it was not gold, but they believed that if they could but discover exactly the proper proportions to put together they would succeed in producing the more valuable metal, as good as any from nature's best mine. This change may be further illustrated by putting a few copper cents into a solution of mercuric nitrate and allowing them to remain a few minutes. Upon removing and rubbing them for a moment they seem to have become silver. It is not strange, therefore, that they should have believed in the transmutation of the metals and that the chief aim of the chemist of the alchemistic era was the preparation of gold from the baser metals.

3. **Old Methods of Reasoning.**—Aristotle, born 384 B. C., one of the greatest of ancient philosophers, once proclaimed that "a globe full of ashes or sand will hold as much water as if empty." Such was the manner of thought of that day that no one for centuries presumed to question the statement. At the present time no scientist would dare publish anything as fact which he did not feel sure was based upon a large number of careful and accurate experiments. Any scientific statement now as soon as published is subjected by scores of scientists to the most rigid tests, so that a few weeks or months at the outside demonstrate the truth or falsity of the position. Not so in Aristotle's time. The very fact that he had stated the proposition was sufficient, and no one even thought of making the experiment, simple as it was, to determine whether the assertion were true.

Twelve hundred years later, Geber, the great Arabian chemist whose doctrines were spread throughout Europe after the Saracen invasion of Spain, declared that all the metals were but different mixtures of mercury and sulphur; that silver and gold were especially rich in mercury and the baser metals were abounding in sulphur. It seems that Geber was somewhat of an experimenter and was forced to admit to himself, at least, though he never did to the public, that the mercury and sulphur as he knew them in the laboratory would not bring about such results as his theory maintained; further that the mercury and sulphur in the free state were not identical with what he described as the same in combination: yet, in spite of all this, he never admitted the inaccuracy or falsity of his theory. Furthermore, his disciples all over Europe, accepted his doctrines with equally unquestioning faith as had those of Aristotle during all the preceding centuries.

Five hundred years passed away and with them the age of alchemy. The first half of the sixteenth century introduces a new school of chemists, the physician chemists, or *iatrochemists,* as they are generally known. Of these, Philippus Aureolus Paracelsus Theophrastus Bombastus, or, as he is usually called, Paracelsus, was easily the leader. He maintained that "Man is a chemical compound. His ailments are due to some alteration in his composition and can only be cured by the influence of other chemical compounds." His belief that the body is composed of mercury, sulphur and salt, it will be readily seen, was but a modification of the ideas of Geber. An increase of sulphur in certain organs of the body caused fever; of mercury, paralysis; of salt, diarrhea and dropsy. Too little sulphur resulted in gout; and so on, for all the ills of mankind. With this theory accepted as the truth, it was but a short step to the giving of calomel for a great variety of ailments, presumably with the assumption that the digestive organs with more discretion than the mind would send the mercury to those organs most in need of it. Here, too, undoubtedly, began the use of sulphur so extensively as a medicine, which in the practice of Paracelsus met with such wonderful results that even the sceptical nineteenth century did not succeed entirely in stopping.

4. **Modern Ideas.**—In time, however, all this passed away. Robert Boyle, born in 1626, expressed disbelief in the four elements of the ancients as well as in the one, to which some held, and declared there were many primary substances to which he gave the name of *elements.* Furthermore by his own example he emphasized the truth which had been dawning for years upon the scientific world that only through experiment can absolute scientific knowledge be determined. Such was his influence that he is often called the "Father of Physics and Chemistry."

With the birth of new ideas as to the composition of matter and a disbelief in the transmutation of the metals, medicine and chemistry became separate sciences, each imbued with the spirit of making sure by experiment of any position taken. Today, medicine no less than chemistry permits of no dogmatic theory as to disease. If a new scourge appears as did yellow fever some years ago, numbers of young physicians are ready to offer their lives, if need be, to learn the true cause; the x-ray reveals to the surgeon the exact condition of the broken bone or the location of the bullet for which he must search; it shows the ulceration at the base of the tooth or other abnormal conditions and renders sure the operation. In the laboratory culture the microscope shows the tubercle bacilli or the diphtheria germ as well as various others. So, in countless ways the modern physician makes sure of his diagnoses, after which proper treatment is comparatively simple.

5. **What is an Element?**—An element in the sense in which Boyle used the term and as used at the present time is a substance which consists of a single kind of matter, hence is not capable of being reduced to anything simpler. There are now known a few more than eighty of these simple substances, but it is possible that some of the rarer of them may not be really elements. It is probable also that others may be added to those already known. Some of the commoner ones are the metals, gold, silver, lead, mercury, aluminum, etc. and oxygen, nitrogen, hydrogen, carbon, sulphur and chlorine.

6. **Compounds.**—A compound is a substance containing two or more elements chemically united, always in exactly the same proportion by weight. For example, water is a compound, consisting of eight parts of oxygen and one part of hydrogen, from which proportions it never varies.

Compounds, How Named.—Chemists have agreed upon and rigidly adhere to a plan of naming compounds in such a way as to indicate the composition as nearly as possible. Thus mercuric oxide is a compound which contains only mercury and oxygen; any compound whose name ends in *ide* contains only the elements named, and with the exception of hydroxides, contains only two elements. Thus, potassium chloride contains potassium and chlorine; magnesium bromide, magnesium and bromine; while sodium hydroxide contains sodium, hydrogen and oxygen. If the name of a compound ends in *ate* the fact is indicated that it contains oxygen in addition to the two other elements mentioned.

Thus, potassium chlorate contains potassium, chlorine and oxygen: copper sulphate, copper, sulphur and oxygen.

Parts of a Compound.—It is well known that a magnetic needle, suspended by a thread or upon a pivot, always points approximately north and south. We often speak of the two ends of the magnet as the positive pole and the negative pole. In an electric circuit, the electrode where the current enters is called the *anode,* or *positive electrode,* and the one where it exits, the *cathode,* or *negative electrode.* Of course the terms, *positive* and *negative* have no real meaning and are used merely for convenience in referring to certain portions of the circuit. Anode and cathode mean, respectively, the *path* or *road in* and the *road out.* Furthermore, it is well known that the positive pole of a magnet always repels the positive pole of another magnet, but attracts the negative pole: from this fact is derived the law stated in physics that "Like poles repel, and unlike poles attract."

Generally speaking, the eighty elements mentioned above may be roughly divided into two groups, *positive* and *negative.* This fact grows out of the law stated just above and shown by the following experiment. If a solution of common salt, sodium chloride, is subjected to the passage of an electric current, the sodium always goes to the negative electrode and the chlorine to the positive: likewise in a solution of potassium bromide, the potassium will be found collecting at the negative electrode and the bromine at the other. Experiments upon compounds of all the elements show like results, hence the statement at the beginning of this paragraph. In the main the so-called metals are positive and the nonmetals are negative. Furthermore, in the study of compounds we find that as a general rule they all consist of a positive and a negative element, or group, united with each other. Thus, sodium chloride contains sodium, positive, and chlorine, negative; potassium sulphate, positive potassium, and negative, the group sulphur and oxygen, which will be more fully explained later. It would seem, therefore, that the force which holds elements together in a compound is electrical in nature. In fact, the expression "chemical affinity" used so often in times past has no real meaning and is seldom used now. One more thing should be observed by the student and that is that in writing or reading the name of a compound the positive part is always given first as a general rule. Thus, chromium nitrate may be a compound entirely unknown to the student, yet from the fact just stated, he may know that chromium is the positive element in the compound and the negative portion is the group containing nitrogen and oxygen.

7. **Mixtures.**—Mixtures are different from compounds in that the two or more substances of which they are composed are not chemically united and are not necessarily in any fixed or definite proportion. Thus, brass is a mixture of zinc and copper in greatly varying proportions. It may contain 65 per cent of zinc and 35 per cent of copper or it may run as low as 5 per cent of zinc and the remainder of copper, with variations all the way between these limits, according to the purpose in view. The air, likewise, is a mixture, mainly of five substances; two of them, nitrogen and oxygen, are always nearly in the same proportion, so nearly in fact, that for many years they were regarded as being combined, but later more accurate measurements showed that even these two vary at different times and places Further, in another chapter it will be shown that there

are excellent reasons for assuming that they are not chemically united.

8. **What is Chemical Union?**—The expression "chemically united" has been used several times in the preceding paragraph. By it is meant that two or more elements in uniting chemically form a new substance, having properties essentially different from those of the original elements, while they lose their individual identities. Thus, water was said to consist of hydrogen and oxygen: at ordinary temperatures these are both gases, one very highly inflammable, the other necessary for all ordinary combustion. When chemically united, the resulting product is a liquid at ordinary temperatures, not combustible like the hydrogen, not an aid to combustion like oxygen. In uniting chemically the two elements have lost their individual characteristics and have formed a substance altogether different from either. To illustrate again, sodium is a silvery white metal, lighter than water which it decomposes rapidly and which in the mouth or upon the wet hand would readily catch fire and produce most serious chemical burns. Chlorine is a heavy, yellow, corrosive gas, used in the World War as a terribly destructive agent: combine these two poisonous elements and we have common salt, used daily in our food and in moderate amounts perfectly harmless. In combining, each element has lost its destructive properties and formed a substance of the greatest commercial value.

9. **Chemical Change.**—A chemical change is one in which the substances used, one or more, are destroyed as such; new substances are formed with entirely different properties. Chemical union, explained in the preceding paragraph, is but one kind of chemical change. Such as those mentioned, the union of hydrogen and oxygen to form water or of sodium and

chlorine to form salt, are called *additive reactions;* that is, the two or more substances have simply been combined to form *one* new substance. An experiment easily made to illustrate this kind of chemical change is that of burning a few inches of magnesium ribbon. The steel gray metal rapidly combines with the oxygen of the air and produces *magnesium oxide,* commonly known as magnesia.

A second kind of chemical change is called *simple decomposition* which is just the reverse of an additive reaction. A single substance by heat or some other force is decomposed forming usually two simpler substances When a current of electricity is passed through water, it is decomposed into its constituents, hydrogen and oxygen. Again, if a small quantity of mercuric oxide is heated in a test tube, in a short time mercury will be seen gathering upon the sides of the test tube while the presence of oxygen at the mouth of the tube may be shown by its causing a glowing pine splinter held just above to burst into a flame.

A third kind of chemical change is known as *metathesis,* or *double decomposition.* It is the mutual decomposition of two reacting substances, resulting in the formation of two entirely new substances. For example, if a small quantity, say about a gram each, of mercuric chloride and of potassium iodide be rubbed together in a mortar, almost immediately the white mixture begins to turn pink and increases in color as the rubbing proceeds. The very fact that two white compounds put together produce a red one indicates something more than mere mixing has occurred. No two white paints could be mixed together to produce a red pigment. What really has happened is this: the two metals, potassium and mercury, being of positive character, as suggested in a preceding paragraph, have exchanged places with each other forming two new compounds, mercuric iodide and potassium chloride, one of which is a brilliant red.

In the study of chemistry we are dealing much of the time with chemical changes most of which will fall under one of the three kinds just mentioned. Some will be of a mixed character, partaking of the nature of two of the kinds mentioned.

Exercises for Review

1. Name the four substances regarded by ancient philosophers as primary.

2. Give some evidence they offered for such belief. Why did they assume one of these could be transformed into another?

3. What led them to believe the metals could be transmuted? What is meant by transmutation of metals?

4. What was the method of scientific reasoning in Aristotle's day? Illustrate. Who was Geber? What was one of his theories?

5. Who was Paracelsus? What was his idea about the human body? Of disease?

6. Who was the father of physics and chemistry? What was his idea about matter?

7. What is an element? How many are there?

8. What is a compound? Name two.

9. How may you know from the name the composition of a compound? Illustrate.

10. What is a magnet? Pole of a magnet?

11. What is meant by anode? Cathode?

12. Into what two groups may the elements be divided? Why so divided?

13. What force apparently holds elements together in a compound? What is chemical affinity?

14. How is a mixture different from a compound? Illustrate.

15. What is meant by chemical union? Illustrate.

16. What is a chemical change?

17. Name three kinds of chemical change. Give some experiment to illustrate each.

18. Define each kind of chemical change.

CHAPTER II

WATER AND ITS COMPOSITION

Outline—

1. Water, Abundance, Various Forms.
2. Water in Food Products.
3. Composition of Water—Proof.
    (a) By Electrolysis—Volumetric.
    (b) By Synthesis—Gravimetric.
4. Deliquescence.
    (a) Definition and Illustration.
    (b) Hygroscopic substances.
5. Water of Combination—Hydrates.
6. Efflorescence.
7. Solvent Powers of Water.
    (a) Hard Waters.
    (b) Water Supplies.
8. Nature's Method of Purification.
9. City Water Systems.
    (a) Sewage in.
    (b) Methods of Treatment.
    (c) Treatment for Algæ.
10. Tests for Water.

Exercises for Review.

1. **Abundance.**—Water in its various forms is so familiar to every one that little need be said of its abundance. As a liquid and in a partially condensed form of steam, fog, and cloud it is known to all; while as ice and snow, glaciers and icebergs, it is known only in middle and northern latitudes.

2. **Water in Food Products.**—Practically all our foods contain a greater or less amount of water. Even flour,

which might be thought of as entirely free from water contains a very considerable amount, averaging in different samples about ten or eleven per cent.

TABLE

	Per cent
Beans, dry	12.60
Beans, string,	89.00
Bread, yeast	36.12 to 37.70
Cabbage	91.50
Carrots	88.20
Cauliflower	92.30
Celery	94.50
Cheese	34.38 to 38.60
Corn	13.12
Eggs	73.67
Flour, wheat	10.11
Meat, lean beef	67.00 to 70.00
Meat, lean pork	60.00
Meat, veal	73.30
Mutton	50.20
Oat Meal	12.37
Peas, dry	12.62
Peas, green	79.93
Potatoes, sweet	75.00
Potatoes, white	66.10 to 80.60
Rice	13.11
Turnips	89.60
Watermelons	92.40

Likewise, all fresh fruits run high in water, their chief food value being in the sugar they contain, in addition to the organic acids probably of special value in their effects upon the digestive system. Naturally, therefore, the human body itself is largely water, it being estimated that in the case of a man weighing 150 pounds the amount of solid matter would be about sixty pounds.

3. **Composition of Water.**—As already stated, water was regarded by the ancient philosophers as one of the primary substances; but we know now that it is a compound, consisting, by volume, of hydrogen, two thirds, and oxygen, one third. Proof of this is usually made by means of what is known as the Hoffmann apparatus, shown in Fig. 1. *A* and *K* are two platinum strips serving as the electrodes and connecting with the electric circuit by means of wires enclosed in glass tubes passed through the corks *C,C,* which close the apparatus at the bottom. *S,S* are stopcocks by means of which the gases may be drawn off at the close of the experiment and tested. *R* is a reservoir to receive the excess of water from the electrolytic tubes, *B,B.* In making the experiment, water slightly acidulated with sulphuric acid is poured into the central tube, or reservoir, and the stopcocks opened to allow the water to just barely fill the tubes, *B,B,* up to the stopcocks. A suitable, direct current is then switched on and allowed to flow until a sufficient amount of gas has collected

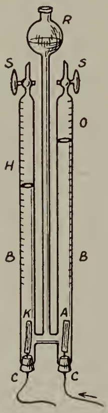


Fig 1.—Electrolysis apparatus.

for testing. Readings taken on the graduated tubes at any time show twice as much gas in one as the other. To prove that the gases are hydrogen and oxygen the following tests may be made which it will be found later are the usual ones. Over the tip of the tube containing the lesser amount of gas, hold a pine splinter with a spark upon the end of it; open the stopcock cautiously and allow the gas to flow out upon the spark: it immediately bursts into a flame. This may be repeated several times, until the gas is exhausted. To test the other tube, with a match or small candle, which is better, light the gas which flows out upon opening the stopcock; it will burn with an almost invisible flame, which is characteristic of hydrogen.

It will be found that in the electrolysis of water as outlined above the hydrogen always goes to the cathode and the oxygen to the anode. The reason for this is plain when we remember what was said about every compound in the preceding chapter, that is, that it consists of a positive and a negative element or group. Hydrogen belongs to the positive elements and oxygen to the negative, hence obeying the law previously stated they would be attracted, the former to the negative electrode and the latter to the positive.

Composition by Weight.—By the electrolysis of water as just given we learn its composition by volume. It is even more important to know what it is by weight. This may be readily determined by a simple experiment as follows:

In Fig. 2, *K* is a generator for the preparation of hydrogen; *W* is a wash bottle containing sulphuric acid for the purpose of thoroughly drying the hydrogen; *T* is a combustion tube made of hard glass containing copper oxide, preferably in what is known as "wire form;" U is a U-tube containing calcium chloride, a substance which rapidly absorbs water; B is a Bunsen burner or some other source of heat. Before beginning the experiment several grams of copper oxide are placed in the combustion tube and both together weighed; next the calcium chloride tube is nearly filled and weighed. Heat is then applied and the current of hydrogen turned on, slow at first. Soon the black oxide will be noticed turning red like bright copper and this will continue till the whole mass has thus changed. At the same time water will be noticed collecting in the U-tube. At this stage the heat is removed but the gas is allowed to continue till the copper oxide tube has become nearly cool. The apparatus is then disconnected and second weighings made. The following weights may be taken as representing a typical case.

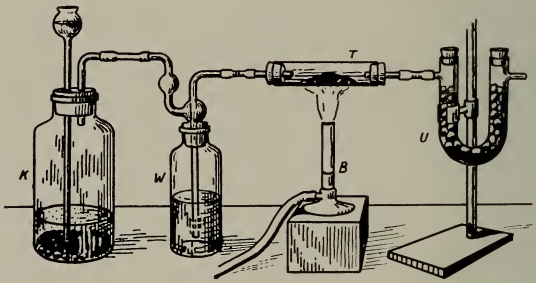


Fig. 2.—Synthesis of water.

Copper oxide tube, before heating	35.29	grams
after heating	28.81	"
Loss, which is oxygen	6.48	"
Calcium chloride tube, before heating	27.34	grams
after heating	34.63	"
Gain, which is water	7.29	"

Subtracting the weight of the oxygen from that of the water leaves 0.81 grams, which is the weight of the hydrogen used in forming the water. It will be observed that this weight is one eighth that of the oxygen or one ninth that of the water formed. Owing to experimental errors the results are not usually exact, but the average of a very large number of experiments more carefully carried out than can be done in the ordinary class room shows conclusively that the above conclusions are correct.

4. **Deliquescence.**—Deliquescence is the property some substances possess of absorbing water from the air when exposed and of becoming liquid. Nearly everything absorbs some moisture when exposed to the air, but a few substances do this to a remarkable degree as indicated in the definition of deliquescence just given. Literally translated the word means "becoming liquid." An excellent example of such compounds is seen in calcium chloride used in the experiment outlined in the preceding paragraph. Other well-known deliquescent compounds are caustic soda and potash and phosphorous pentoxide. A hygroscopic substance is one that will become damp upon exposure to the air, but will not absorb sufficient water to become a liquid. Most samples of table salt become damp in wet weather due, however, to the presence of an impurity in the salt rather than to the salt itself being hygroscopic.

5. **Water of Combination—Hydrates.**—Many chemical compounds occur in regular geometric shapes which are called crystals, such as cubes, octahedrons, rhombohedrons, etc. These crystals are more often obtained by making a solution of the substance in water and evaporating. In such cases it is often true that a very con-

siderable portion of the water, instead of passing off into the air, goes into combination with the solid. Water thus taken up is called *water of combination* or often, though less properly, *water* of *crystallization.* This water is not simply mixed with the solid: if it were, it might be removed by pressure or absorption by a piece of blotting paper. On the other hand, it is far from a stable chemical union, for usually comparatively little heat will more or less completely remove it. That there is real chemical union, however, is known from the fact that when the water is removed the properties of the substance are often materially changed. Such substances as these are now called *hydrates.* Some good examples of crystalline hydrates are blue vitriol, alum, green vitriol, sal soda, borax and many other familiar compounds.

To illustrate how removing the water from such a compound changes its characteristics, put a few small crystals of blue vitriol into a test tube and cautiously heat it in the Bunsen burner. Water will be seen collecting upon the upper, cooler portions of the tube and the copper sulphate itself will lose its crystalline structure and at the same time its blue color. When all the color has disappeared, allow the tube to cool and add a few drops of water. The blue color is instantly restored and upon evaporating the excess, the crystals will again form. It must be believed therefore, from the fact that adding water, itself colorless, to a compound also colorless (white) gives a blue compound, that some chemical action has taken place to produce so remarkable a change. It will be found if other hydrates are thus tested that they invariably lose their crystalline structure when the water is expelled and if they are colored, they lose their color also.

In referring to these crystalline compounds it is often not necessary to use any expression indicating that they contain water; but when such is desired it is customary to use the word *crystallized* or some other expression. Thus, we would say crystallized copper sulphate; or, if the compound without the water was intended, we say *anhydrous* copper sulphate or whatever the compound may be. The term *anhydrous* means *with water removed.*

6. **Efflorescence.**—As stated in the preceding section, water of combination may be removed more or less readily by application of heat. In many cases the temperature of an ordinary room is sufficient to cause the loss of the combined water. Such substances are said to be *efflorescent.* The word means, literally, *becoming flour* or *a powder* and is thus used because when loss of the water occurs the crystals crumble to a powder. Efflorescence, then, would be defined as the property which many hydrates possess of giving up their water of combination on exposure to the air and becoming a powder. An excellent example of such compounds is common washing soda or sal soda; also ferrous sulphate, and blue vitriol to a considerable extent.

7. **Solvent Powers of Water.**—Water is a nearly universal solvent. Practically every mineral in time will dissolve to a greater or less extent in water. As a result all spring water is more or less "hard" as it has dissolved portions of the rocks through which it has passed. The virtue of water in therapeutics, applied in the case of certain fevers and some other diseases, probably lies in its high absorptive powers. No one thing is guarded more zealously in every city than its water supply. Contamination of cisterns, springs and wells by cess pools or from similar sources is so easy

that the use of such water is seldom safe in any thickly settled community. Appearance of the water is no guide; chemical and bacteriologic tests are the only way of knowing certainly and these should be appealed to whenever there is the slightest doubt in the matter.

8. **Nature's Method of Purification.**—Sunshine and air are Nature's greatest enemies to many impurities in water. In open, flowing streams, in a comparatively short time, sunlight and the oxygen of the air destroy the greater portion of impurities which find their way into the water by means of sewage. A noted example was brought to the attention of the public some few years ago when the city of St. Louis brought suit in the courts against Chicago, complaining that the latter city was contaminating the water supply of the former. This claim was based upon the fact that Chicago had dredged out the upper channel of the Chicago River, dug a canal across to the Illinois River and was thus sending her sewage down to the Mississippi River instead of into Lake Michigan as formerly. Chemical experts employed in the case after making careful analyses testified that the sewage in crossing the state was entirely oxidized and purified before reaching the city of St. Louis.

Notwithstanding this fact, typhoid and other disease-producing germs often withstand these forces of Nature and too great care can not be exercised in daily examinations of the water supply in every city.

9. **Methods of Purifying City Water Supply.**—The method followed must naturally depend upon the source of supply. If this is a river, which often carries more or less material in suspension, settling basins or filtration beds or both must be installed. For a large city settling basins must be of very considerable size and

are divided into compartments. Into one or more, where the water with its load of mud in suspension is received from the river, a stream of milk of lime and a solution of aluminum sulphate or some similar substance are run by gravity. These on coming together in the water produce a gelatinous coagulum which settles somewhat rapidly, carrying with it the mud and most of the bacteria, from the fact that they are generally attached to mud particles. At intervals this deposit is washed back into the river below the intake. The water is now clear but still may contain pathologic bacteria. Hence as it enters the great pipes on its final journey to the city it is treated with liquid chlorine, or chlorinated lime in solution, or some similar substance, in small but sufficient amounts to render it perfectly safe for domestic use. Where filtration beds are used, these consist of basins or chambers with thick layers of sand over gravel or tiling through which the water filters, leaving its sediment behind. For large cities using water carrying a considerable amount of mud, a combination of settling basins and filtration beds is desirable. An idea of these may be obtained from Fig. 3.

Another Problem.—In some portions of the country, the water supply is not obtained from running streams, but from reservoirs in mountain valleys or small lakes. Often in such cases another serious problem confronts the chemist. There is no sediment to be removed, but in the summer months certain algæ, a species of plant to which the green scum seen on stagnant water belongs, grow abundantly upon the surface; as autumn approaches, they produce spores which burst, rendering the water exceedingly offensive in odor. To prevent this such reservoirs now are treated with blue vitriol.

A burlap sack filled with the copper sulphate crystals is suspended in the water from the stern of a skiff and two men row back and forth across the lake until the compound has all been dissolved. This may require several days. It has been found that the merest trace of blue vitriol in the water prevents the growth of the algæ, yet at the same time will have no serious effect upon the human system. An instance of this is the famous Sweetwater Dam in Southern California, holding billions of gallons of the finest water from the mountain snows, sufficient for San Diego, National City and all the surrounding territory.

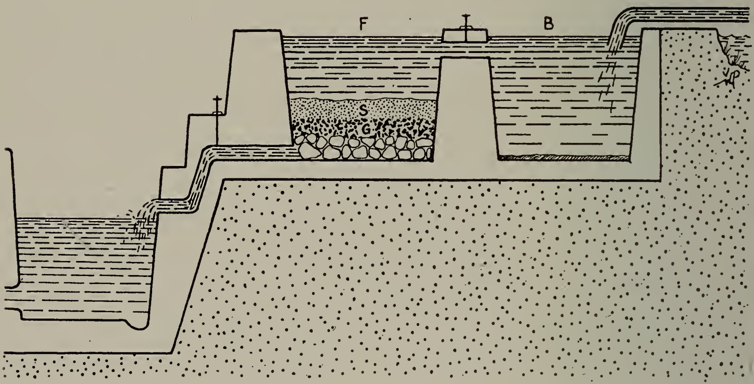


Fig. 3.—Diagrammatic view of city water plant. *B*, the settling basin; *F*, the filter, in the bottom of which are layers of sand and gravel, indicated by the letters *S* and *G*.

10. **Some Simple Tests for Water.**—Many liquids resemble water in appearance and sometimes it is important to determine positively whether they are water or some other compound. Pure water has no color, no odor, no taste, will not affect either red or blue litmus paper, leaves no residue on evaporation, and will turn anhydrous copper sulphate blue. It is often said that

pure water tastes flat; this is because we are accustomed to drinking that which contains more or less foreign matter which really gives it some taste. The above tests, however, applied to any liquid resembling water will usually be sufficient to determine.

Exercises for Review

1. Give some of the familiar forms in which water occurs.
2. Name some of the familiar food products with amount of water contained.
3. What is the amount of water in the human body?
4. Give the electrolytic proof for the composition of water.
5. Why does the hydrogen go to the cathode? The oxygen to the anode?
6. Describe the synthetic proof for the composition of water.
7. What is deliquescence? Name two such substances.
8. What is a hygroscopic substance?
9. What is a hydrate? Water of combination? Give illustrations.
10. How may water of combination be removed?
11. What is meant by anhydrous? How could you prepare anhydrous copper sulphate?
12. What is efflorescence? Illustrate.
13. What is hard water? How does it become hard?
14. How may we know if water is pure for drinking?
15. How does nature purify water in streams?
16. Give some methods used by cities in purifying river water for use.
17. What treatment is often necessary for water derived from lakes?
18. Name some of the simple tests which may be applied for water. Would these give any evidence as to purity?

CHAPTER III

HYDROGEN

Outline—

1. Brief History of the Gas.
2. Hydrogen in Nature.
3. Ways of Preparing Hydrogen—
    - (a) From Water, First by Electrolysis; Second, by Metals Like Sodium.
    - (b) From Acids, Especially Sulphuric and Hydrochloric, with Zinc or Iron.
    - (c) By Heating Oils, Like Kerosene, in Absence of Air.
4. Acids as a Source of Hydrogen.
5. Characteristics of Hydrogen.
6. Uses of Hydrogen—
    - (a) In Oxyhydrogen Blowpipe;
    - (b) In Balloons.

Exercises for Review.

1. **Discovery of Hydrogen.**—It is probable that the great physician chemist, Paracelsus, prepared hydrogen. At least we may judge so from the fact that he carried out experiments involving the evolution of hydrogen as a by-product. However, if he did, he made no study of the gas, and as he does not mention it in his writings, it possibly escaped his notice entirely. It was not till 1766 that Cavendish, the great English chemist, prepared and recognized in hydrogen a gas hitherto unknown and made a careful study of it. In accordance with the ideas of the time, from the fact that it is highly combustible, he gave it the name of

inflammable air. Although it was Cavendish who first proved that water consists of hydrogen and oxygen, nevertheless, he did not regard it as an element and it was not until toward the latter part of the century that it was so recognized and received the name of *hydrogen,* meaning *water producer.*

2. **Hydrogen in Nature.**—Although not found free upon the earth in appreciable quantities, hydrogen is a constituent of many compounds and is very widely distributed. First of these in importance is water, of which as already seen it is ⅔ by volume and ⅑ by weight. Second, it is found in all acids, many of which exist in nature: thus, citric acid in lemons and grapefruit; tartaric in green grapes; oxalic in rhubarb, etc. Third, organic compounds, by which we now generally mean carbon compounds, of which considerably over 100,000 have been prepared and studied. Familiar among these are sugar, starch, fats, oils, etc.

3. **Preparation of Hydrogen.**—In preparing any element for study naturally we should expect to use some compound containing that element; so in the present case we turn to one or more of the substances mentioned in the preceding section. In another chapter we have already studied a method of obtaining hydrogen from water by electrolysis. While this way gives a very pure gas, with the apparatus at hand in the ordinary laboratory, it is slow and expensive, hence seldom used as a source of hydrogen.

It has been stated elsewhere that the elements may be divided roughly into two groups, electropositive and electronegative. Moreover, we have seen that hydrogen is electropositive. At this time it must be stated further that some positive elements are more strongly positive than others. It is well known that a bar magnet shows strong magnetism at the *poles* or ends, while the property rapidly diminishes toward the center. (See Fig. 4.)

In a general way we may compare the metals to the positive half of the magnet. Starting with potassium

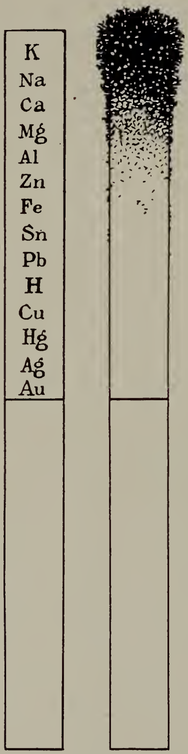


Fig. 4.—Electromotive series of metals.

we have a very strongly positive element, next is sodium, and so on until we come to hydrogen, tenth in number in the illustration. Following hydrogen are several other common metals, less positive. If we stop to think about it, remembering that all compounds are composed of a positive and a negative part, we should expect that, in water, for example, any metal more positive than hydrogen would be able to deprive the hydrogen of its oxygen and set the hydrogen free. Now, potassium, very strongly positive, does this so violently that the heat generated is more than sufficient to ignite the gas instantly, volatilizing a small amount of the potassium and coloring the flame violet. Sodium, next in order, also decomposes water rapidly but on cold water not sufficient heat is generated to ignite the hydrogen, although this will happen if the water has been previously warmed. As we go down the scale the action is less and less rapid, some requiring boiling water, while those near hydrogen act very, very slowly.

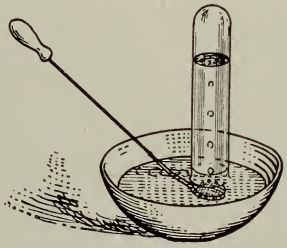


Fig. 5.—Preparing hydrogen from water.

A convenient method of collecting hydrogen when sodium is used is shown in Fig. 5. A small piece of sodium is enclosed in the gauze spoon and placed under a test tube or small bottle full of water inverted over a trough of water. Bubbles of gas rise rapidly from the water and fill the tube. To show that the gas is hydrogen it may be lit and will be seen to burn with an almost invisible flame as was the case in the electrolysis experiment. In this connection it is interesting to note that a bit of sodium dropped upon a dish of water rolls around, gradually becoming smaller. By touching a lighted candle to the metal the hydrogen catches fire and burns with a yellow flame due to the volatilization of a small amount of the sodium.

4. **Acids as a Source of Hydrogen.**—Neither of the methods outlined above for obtaining hydrogen from water is well suited where considerable quantities are desired. Acids are found far preferable: however, such acids as hydrochloric and sulphuric instead of the organic ones previously mentioned are used. As in the case of water, a metal is used to displace the hydrogen and for the same reason. Experiment has shown that the metals higher up in the series act too violently with the acids named; moreover they are very expensive. Therefore, zinc, sixth in the series, or iron, seventh, is more often used, the former giving the purer gas and therefore preferred for class study. The method is shown in Fig. 6. *F* is a generating flask of about 250 c.c. capacity; it is fitted with a two-hole cork; thistle tube, *T;* elbow, *E,* rubber connection, *R;* delivery tube, *D.* Several bottles are filled with water and inverted over the pneumatic trough, *P.* When everything is ready, sufficient mossy zinc is put into the flask to cover the bottom, the cork is replaced snugly, water is poured

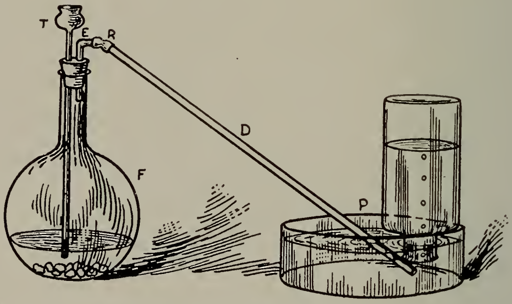


Fig. 6.—Preparing hydrogen from acids.

through the thistle tube to cover the zinc, and seal the tip of the thistle tube, then sulphuric acid is added, a small amount at a time till the action begins. A large amount of acid will stop the action almost entirely. The process may be hastened greatly by pouring in a few cubic centimeters of a solution of copper sulphate. The first bottle collected will be mostly air and should be discarded.

5. **Characteristics of Hydrogen.**—From the experimental study of hydrogen it will be learned that it is a colorless gas, odorless, lighter than air, not soluble in water, is very inflammable, explosive when mixed with air, and extinguishes a flame when inserted into a mass of it, or as it is generally expressed, does not support combustion. More detailed experiments have shown that hydrogen is the lightest of all gases, being only a little more than one fifteenth as heavy as air. It requires over eleven liters of it, about eleven quarts, to weigh one gram, the weight of one liter being a little less than .09 gram. It burns with an intensely hot flame, one gram of it producing more than four times as many heat units as an equal weight of anthracite coal. It easily passes through unglazed earthenware, or the crack of a bottle that will not leak water or other gases, and toy balloons filled with it soon lose their buoyancy for the reason that the hydrogen escapes through the pores of the rubber itself. It is rapidly absorbed by certain metals, as platinum and palladium, especially the latter, producing heat. This is called *occlusion* and so much heat is generated that a platinum sponge lowered into a bottle of hydrogen and oxygen mixed, will almost instantly explode the mass with violence.

6. **Uses of Hydrogen.**—(*a*) *The Oxyhydrogen Blow-*

pipe or Torch.—There are several patterns of the oxyhydrogen blowpipe, but they all amount to the same thing. They have one pipe which introduces a supply of oxygen within another pipe furnishing hydrogen, at a point shortly before that at which the mixture is to be burned. It gives an intensely hot flame, ranging from 2,000° to 2,500° C., 3,600° to 4,500° F., and is used in melting refractory metals or other substances. Up to the introduction of the electric arc light, the *calcium,* or *Drummond,* or *limelight,* by all of which names it is known, was used almost exclusively for stereopticon work and stage lighting. This was secured by allowing the flame of the blowpipe to impinge upon a prepared stick of lime, which became white hot, dazzling in brightness. See Fig. 7 for a common type.

Fig. 7.—Oxyhydrogen blowpipe.

(*b*) *Use in Balloons.*—At the present time observation balloons and dirigibles are using immense quantities of hydrogen and serving a valuable purpose. Natural gas is sometimes used instead of hydrogen, but it is about eight times as heavy, hence not nearly so desirable. Sometimes from amusement parks or county fairs balloons are sent up, from which the aeronaut after a short time jumps with a parachute. As he does so, usually the balloon capsizes and a puff of smoke appears. This is understood when it is known how such balloons are usually filled. At the beginning of this chapter it was stated that organic compounds, such as oils, all contain hydrogen. So, for such brief flights, kerosene, or some similar oil, is run in gradually upon a bed of hot coals in a furnace with draughts closed to exclude the air. The heat decomposes the oil into a number of gases, about 45 per cent of which is hydrogen and these are passed by a pipe into the balloon. Smoke is always an indication of imperfect combustion, and in this case that seen is due to the partial combustion of a small amount of the oil owing to the fact that it is impossible to keep out all traces of air.

Exercises for Review

1. By whom and when was hydrogen discovered? What did he call it? Why?

2. When did it receive its present name? Why?

3. Name three classes of substances containing water. Give proportion in most abundant one.

4. How may hydrogen be obtained from water? Give two ways.

5. What may be said of the purity of the gas obtained this way? What may be said of the value of these methods for obtaining large amounts?

6. What is said about the electromotive series of metals? Where does hydrogen come in this series?

7. What is true of any metal before hydrogen in the series? After hydrogen?

8. Illustrate with potassium; with copper.

9. Describe method of obtaining hydrogen from water by sodium.

10. What is the best way to prepare large amounts of hydrogen? What acids are best?

11. What metals are used with these acids? Why not sodium?

12. Give six characteristics of hydrogen.

13. What is said of the heat obtained from burning hydrogen? What application is made of this fact?

14. What use is made of hydrogen because of its lightness? What substitutes may be used? What disadvantage has each?

CHAPTER IV

THE ATMOSPHERE

Outline—

1. Various Ideas of the Air.
    - (a) In Time of Aristotle.
    - (b) In Eighteenth Century.
2. Composition of the Air.
    - (a) Components.
    - (b) Amounts of Each.
3. Proofs that the Air is a Mixture.
    - (a) Absorption of Its Components by Water.
    - (b) Evaporation of Constituents from Liquid Air.
4. Components Remain Mixed, Why.
    - (a) Densities of the Constituents.
    - (b) Possible Arrangement of Constituents.
    - (c) Wind Currents.
    - (d) Diffusion of Gases.
5. Value of the Oxygen.
    - (a) Warming the Human Body.
    - (b) Problems of a Plentiful Supply.
    - (c) Amounts Required.
6. Purpose of the Carbon Dioxide.
    - (a) Its Effect upon Animal Life.
    - (b) What Indicated by Large Amounts in a Room.
    - (c) How Used by Plants.
    - (d) The Oxygen Cycle in Nature.
7. Carbon Dioxide and Plant Life.
8. The Moisture in the Air.
    - (a) Saturation—Amounts Possible at Different Temperatures.
    - (b) Effect of High Humidity on Body.
    - (c) Problem of Supplying Moisture in Winter.
    - (d) Effects of Lack of Moisture.
9. The Health Problem.

10. Value of the Nitrogen.
    (a) As a Diluent.
    (b) In Nitrogenous Compounds for Body.
    (c) How Secured for Fertilizer.

Exercises for Review.

1. **Early Ideas Regarding the Air.**—As long ago as the time of Aristotle, 350 years before Christ, the air was a subject of interest to scientists. In that day, as already stated, it was regarded as one of the four primary substances; and as they did not seek scientific truth by experimental investigation, for centuries nothing new was learned concerning it. In the latter half of the eighteenth century, however, a number of chemists, especially in England, France, and Sweden, were engaged in a study of the air, various other gases and combustion. But even as late as the time of the American Revolution the idea that the gases already discovered were simply modifications of the air had not entirely passed away. Joseph Black, the discoverer of carbon dioxide, called it *fixed air;* Cavendish named hydrogen, *inflammable air;* Priestley called oxygen, *dephlogisticated air;* Scheele called it *fire air;* nitrogen was known as *phlogisticated air;* even the perfumes exhaled by the flowers were regarded as modified forms of the atmosphere. It was not until near the end of the century that Lavoisier, the great French chemist, applying the careful use of the balance, overthrew the prevalent ideas of combustion, gave the present names to hydrogen and oxygen, and cleared the chemical atmosphere of much that was false and detrimental to progress.

2. **Composition of the Air.**—For a good many years after the air was known to contain several substances, it was not thought of as a mixture; or at least the two more important constituents were regarded as com-

bined and this compound mixed with the others of lesser value. Now, however, we know that the air is a mixture, consisting of nitrogen, oxygen, carbon dioxide, argon, and watery vapor, with very small amounts of several other rare elements. These five are in the following proportions by weight: nitrogen, 75.46 per cent; oxygen, 23.18 per cent; argon, 1.29 per cent; carbon dioxide, 0.04 per cent; vapor, variable.

3. **Proof That the Air Is a Mixture.**—Several very convincing proofs may be offered that the air is a mixture. First, if pure water is exposed to air, it is found that the water absorbs relatively much more oxygen than nitrogen, although there is nearly four times as much nitrogen in the air: if the air were a compound the absorbed portion would necessarily contain the constituents in the same proportion as found in the undissolved part. Moreover a given volume of water will absorb the same amount of oxygen whether it be exposed to air or pure oxygen; the same is true of the nitrogen absorbed. This shows that these gases must be free in the air to act as if they were not together at all.

Second, when air is liquefied and allowed to stand in an open vessel, practically all the nitrogen will boil out leaving nearly pure oxygen, while the carbon dioxide becomes a solid and may be filtered out. Since nitrogen has a lower boiling point than oxygen this is possible, just as alcohol with a boiling point of about 78° C. may be removed from water with a boiling point of 100° C. However, if the nitrogen and oxygen were combined in the air, they would necessarily evaporate in the same proportions as contained in the liquid.

4. **Why Do the Constituents Remain Mixed?**—The gases of the atmosphere have densities differing greatly.

Argon is the heaviest, with a density compared with hydrogen of about 40; carbon dioxide is next, with a density of 22; oxygen, third, density, 16; nitrogen, fourth, 14; watery vapor, 9. If not mixed, argon so heavy, would lie next to the ground to a depth of some 200 feet; the carbon dioxide above the argon, ten or twelve feet deep; the oxygen next, about one mile and then the nitrogen about four miles. This is on the assumption that the air is everywhere the same density instead of becoming rarer as we ascend. Were such conditions to obtain it is evident no life upon the globe would be possible. Two things prevent such an arrangement: one is the wind currents more or less prevalent everywhere which maintain a constant circulation. Another is what is called diffusion of gases. By this is meant that the particles of gas in any closed space free from currents are quickly carried from one portion of the space to another. Thus in a closed room, if an irritating gas is generated in one corner it is soon perceptible in all parts of the room, regardless of whether the gas is light or heavy.

5. **Human Value of Each Constituent.**—The oxygen, constituting about one fifth of the air, is an absolute essential for respiration. When taken into the lungs it is absorbed by the blood and forms there a kind of loose compound somewhat similar to water of combination in hydrates and is thus carried to all parts of the body. In this way the average human being uses daily an actual weight estimated about 750 grams, or 26 ounces of pure oxygen. Meeting the carbon in the tissues, chemical union takes place: carbon dioxide is the result to the amount of about 1,000 grams, or over two pounds. Accompanying this chemical action or as a result of it,

heat is produced and the body warmed. When the air enters the lungs it is about 23 per cent oxygen by weight; when it leaves, it is only about 16 per cent oxygen, while the carbon dioxide has been increased more than one hundred fold. To be more specific, ordinary air contains from 3 to 4 parts of carbon dioxide in ten thousand or from .03 to .04 per cent. On leaving the lungs it contains about 440 parts per ten thousand or 4.4 per cent. It will be seen, therefore, that in a crowded room with poor ventilation the percentage of carbon dioxide rapidly increases. In the ordinary home of the middle and upper classes where the family is usually small, by means of the air leakage from ill-fitting windows and doors there is usually ample ventilation. It is in the densely populated tenement houses of few rooms, kept none too well, where the danger lies; also in school rooms where many children are gathered and in various other places of public gathering such as theatres and moving picture houses where the rooms are tightly closed and the ventilation is poor. The health boards of many states require in school rooms a system of ventilation which will furnish 30 cubic feet of fresh air per minute per pupil. It will be noticed from what was stated in a preceding section that in the first respiration about one fourth of the oxygen is removed; it is approximately true that a second respiration of the same air removes about a fourth of what remains: it is evident, therefore, what the effect of an impoverished air would be upon the purification of the blood, and the importance of a plentiful supply of fresh air.

6. **The Carbon Dioxide.**—Carbon dioxide is not a poison and the amounts found in any ordinary room

could not produce serious results. A person drowns in a well of carbon dioxide just as he does in one of water, simply because oxygen is shut off from the lungs, and not because of any toxic effects of the gas. A high percentage of carbon dioxide, however, is nearly always indicative of poor ventilation and therefore of the presence of large amounts of other gases thrown off from the lungs which are injurious. All expired air contains not merely the carbon dioxide but various other substances, the result of broken down tissue and it is these accompanying products which are to be feared. In breweries where the percentage of carbon dioxide often runs relatively high because it is being evolved in the processes of manufacture, none of the symptoms observed in poorly ventilated crowded rooms appear; this is because the carbon dioxide present is not accompanied by the noxious gases from the products of respiration as in the other case.

7. **Carbon Dioxide and Plant Life.**—Carbon dioxide is an absolute essential of plant growth. Through their leaves all growing plants inhale it and, decomposing it under the influence of sunlight, they store up the carbon in the woody structure in the form of cellulose, while the oxygen is thrown off again to the air. So while in various ways vast quantities of carbon dioxide make their way into the air, in the endless cycle of nature it is being constantly removed by plants and the oxygen necessary for animal life is being restored again.

8. **Necessity of Moisture.**—The amount of moisture the air can hold depends upon the temperature. For example, a cubic meter of air at 0° C. (32° F.) is able to hold only 4.87 grams of water; at 10° C., 9.92; at 20°, 17.16. At these temperatures if it contains the amount

mentioned it is said to be saturated. Quantities ranging between two thirds and three fourths of these amounts are regarded as most suitable for health conditions. High temperatures with high humidity, as is frequent in the Mississippi Valley and Atlantic States in summer, are often attended with serious results, while the same temperatures in the Rocky Mountain States are not found even uncomfortable. The reason for this is evident. The temperature of the human body is regulated by evaporation of moisture from the surface; if the surrounding atmosphere is near the point of saturation the moisture upon the body is not carried away, the cooling process is stopped and oppression results. To evaporate a single gram of water requires something less than 550 calories of heat; or the heat required for the evaporation of an ounce of water if taken from the surface of the body weighing 150 pounds would lower the temperature of the entire body about 0.5 of a degree.

9. **The Health Problem.**—These facts indicate a problem of healthfulness in our homes and public buildings. Assuming 32° F. (0° C.) as the average temperature of an ordinary winter day, if saturated a cubic meter of air could contain but 4.87 grams of moisture. Very seldom in winter except in certain localities does the air approach saturation, more often not over 50 per cent, or less. When this air is heated to 20° C. (about 68° F.) the humidity would be as low as 15 per cent oftentimes. The result is rapid evaporation of the moisture of the body, chapped hands, dry and irritated nasal passages, throat and bronchial tubes. To remedy this is a difficult problem. In large school buildings which are warmed to a greater or less extent by an indirect

system of heated air forced into the various rooms, means are provided for materially increasing the moisture. In homes warmed by steam or hot-water radiators a towel rack such as is found in every bath room can be fastened on the wall behind each radiator, with a towel suspended therefrom and dipping in a pan of water upon the floor. By capillary attraction the water will be drawn up into the towel and then rapidly evaporated by the heat. In houses heated by hot-air furnaces, which are the more common, the problem is more difficult. In many cases, however, an aluminum wire may be fastened beneath the register and a short towel suspended in a pan of water. The main trouble is to keep the pans supplied with water, for the evaporation is surprisingly rapid.

Fig. 8.—Nodules in which the nitrogen-fixing bacteria live on the roots of a bean. (From Warren—Elements of Agriculture.)

10. **Value of the Nitrogen.**—As found in the air in a free state, nitrogen seems to serve little purpose other

than as a diluent for the oxygen. With the air largely oxygen no fire could be kept under control, and the human body as at present organized in all probability would not long remain in health. In the form of compounds, however, nitrogen is of inestimable value. The muscular part of the body is built up of nitrogen compounds and can be repaired only by nitrogenous foods. We can not obtain nitrogen directly from the air and must go either to the plant or the animal kingdom. Moreover, plants can not obtain it directly from the air; to them it must be supplied by soluble fertilizers, which will be considered in another chapter. It should be said, however, that one class of plants, the legumes, have the power, through bacteria which form nodules upon the roots, of absorbing nitrogen directly from the air. Such plants are able not only to make use of this supply themselves, but if plowed under, they leave it in soluble form for other crops. At the present time large areas every year are sowed to cow peas, soy beans, vetch, and various clovers, mainly for the nitrogen-fixing results which follow. See Fig. 8 showing nodules upon the root of a bean plant.

Exercises for Review

1. What was the idea regarding the air in time of Aristotle? Why was so little learned about it for so many centuries?
2. In eighteenth century what relation was supposed to exist between various gases known and the air? Illustrate by names.
3. What chemist did most at clearing up the difficulties?
4. What are the constituents of the air and their proportions?
5. Give two strong proofs that the air is a mixture.
6. If in order of their densities how would the gases in the air be arranged? Give their densities.
7. What two things prevent such an arrangement?
8. State what is meant by diffusion and illustrate.

9. Explain fully the value of oxygen to the human body.

10. Give difference in composition of the air before being inhaled and just after exhalation.

11. What amount of fresh air is deemed necessary in school rooms? How is this secured in private homes?

12. What is the effect of carbon dioxide upon the body?

13. What does a high percentage of carbon dioxide in a room usually indicate?

14. Where does the danger lie in such conditions?

15. Explain what use plants make of carbon dioxide.

16. Show how equilibrium of oxygen is maintained by the cycle in nature.

17. What governs the amount of moisture the air can hold?

18. What is meant by saturation?

19. Air saturated at 0°C. would be what percentage saturated at 10°C.? What at 20°C.?

20. Explain how the body is cooled and the effect of high humidity.

21. Why does an electric fan cool the body when it does not furnish air any cooler than that near the body?

22. What is the effect upon the body of a very dry atmosphere?

23. How may conditions be improved in our homes?

24. State some benefits which may result from a very dry atmosphere. Why?

25. What is the main use of free nitrogen in the air?

26. What use is nitrogen in the body? How secured?

27. How do plants secure their nitrogen?

28. What are legumes? How do they serve as nitrogen-fixing plants?

CHAPTER V

OXYGEN

Outline—

1. History of Oxygen.
    - (a) Date of Discovery.
    - (b) Names of Discoverers.
    - (c) Old Names for the Gas.
2. Occurrence of Oxygen in Nature.
    - (a) In Water.
    - (b) In the Air.
    - (c) In the Earth's Rocky Crust.
    - (d) In the Human Body.
3. Preparation of Oxygen.
    - (a) From Water, by Electrolysis.
    - (b) From Mercuric Oxide.
    - (c) From Potassium Chlorate, with a Catalyst.
4. Experiments with Oxygen.
    - (a) Burning Phosphorus.
    - (b) Burning Charcoal.
    - (c) Burning Watch Spring, etc.
5. Characteristics of Oxygen.
6. Uses of Oxygen.
    - (a) Respiration.
    - (b) Combustion.
    - (c) Medical.
7. Oxygen as Related to Health.
    - (a) In Purifying Waters.
    - (b) In Destroying Noxious Gases in the Air.
    - (c) In Removing Waste Through Decay.
8. Kindling Temperature.
9. Oxidation and Combustion.

Exercises for Review.

1. **Discovery of Oxygen.**—In 1773 or perhaps a little earlier, Scheele, a great Swedish chemist, using manganese dioxide and sulphuric acid, prepared oxygen and carefully studied its properties. In August of 1774, Joseph Priestley, an English chemist, who later in life moved to America, prepared oxygen by heating mercuric oxide. He gave it the name of *dephlogisticated air,* whereas Scheele had called it *fire air* and *life air,* from the fact that he had found it necessary for both. Priestley published an account of his investigations shortly after making them, while Scheele did not do so, hence the former has generally been regarded as the first discoverer. It was not for some years after this that the present name, *oxygen,* meaning *acid former,* was suggested by Lavoisier.

Fig. 9.—Abundance of certain elements.

2. **Occurrence of Oxygen.**—Oxygen constitutes about half of all the material in the world. By weight, water is nearly 90 per cent oxygen; the air about 23 per cent; sandstone, somewhat more than 50 per cent; limestone, 48 per cent; the human body, about 66 per cent; while nearly all the elements form compounds with it. Fig. 9 gives an idea of its relative abundance.

3. **How May Oxygen Be Prepared?**—Either method used by the discoverers of oxygen may be used and sometimes both are. It may also be obtained, as we have seen, by the electrolysis of water. However, a much easier way than any of these and one yielding it more abundantly is by using a compound called potas-

sium chlorate. If a small amount of this, say a half inch in a test tube, be heated, it will be seen to melt first, then shortly begin to boil, and soon thereafter oxygen will fill the tube and ignite a glowing pine splinter held at the mouth. If now into another similar test tube the same amount of potassium chlorate is mixed with about one-third or half as much manganese dioxide, and heated in the same way as before, it will ignite the pine splinter in from one-fourth to one-sixth the same

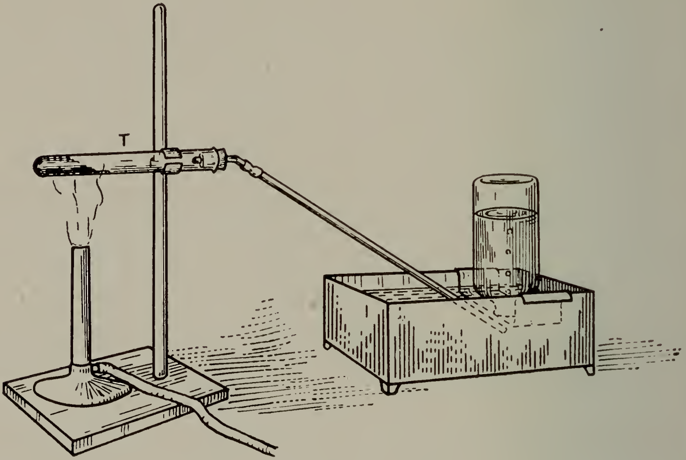


Fig. 10.—Preparing oxygen from potassium chlorate.

length of time. Further experiments, made after all the oxygen has been driven off show that the manganese dioxide has not changed at all; it is still all present, may be recovered and used repeatedly equally as well as the first time. All it has done is to hasten the chemical action by its presence: such a substance is called a *catalyst,* and the process is *catalysis.* It will be found later that many such cases occur in chemistry. Likewise, these catalytic agents exist in the human body in the form of enzymes whose purpose it is to hasten the processes of digestion, also in other places in nature.

For laboratory purposes, oxygen is usually prepared by this method. Fig. 10 shows the usual way of collecting the gas. *T* is a six- or eight-inch test tube about one third full of potassium chlorate and manganese dioxide, well mixed, in the proportion of about four parts of the former to one of the latter. When the receiving bottles are ready in the pneumatic trough, gentle heat is applied until the gas is coming off freely when it is removed until needed again to hasten the action. If only a small amount is desired it may be obtained from a compound of sodium called "oxone" which can now be purchased at the supply houses. No heat is necessary as the gas is readily evolved by allowing water to drip upon it. (See Fig. 11.)

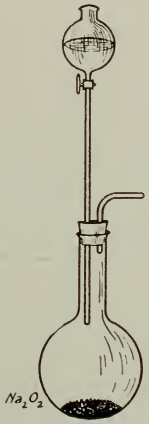


Fig. 11.—Preparing oxygen from sodium peroxide.

4. **Some Experiments With Oxygen.**—(a) Phosphorus ignited in a deflagrating spoon and lowered into a large bottle of oxygen burns with a dazzling white light.

(b) A piece of bark charcoal, fastened on a wire, and heated till it begins to glow, in a bottle of oxygen, bursts into a shower of sparks.

(c) Sulphur, which burns with an almost invisible blue flame in the air, in oxygen is much brighter and deeper blue color.

(d) A watch spring, from which the temper has been drawn by heating, if kindled with sulphur, burns rapidly with a bright display of sparks. These and many other experiments which might be mentioned all show the vigor with which oxygen combines with a large number of substances when heated somewhat above ordinary temperatures.

5. **Characteristics of Oxygen.**—If the above experiments are made carefully the following characteristics will be noticed: that it is a gas, colorless, odorless, heavier than air, shown by the fact that when using a bottle of it, it is left sitting upright upon the table, apparently not soluble in water, combines vigorously with most substances, in contact with the air does not burn. In reality it is somewhat soluble in water, three volumes being absorbed by 100 of water. It is this free oxygen in the water that fishes and other aquatic animals use. It may be liquefied about 182 degrees below zero centigrade and in this condition resembles water except that it is pale blue in color. It is usually said that the gas is colorless but probably what we call the "blue sky" is nothing more than the color of the miles of gaseous oxygen in the air.

6. **Uses of Oxygen.**—Primarily, it should be said that oxygen is necessary for respiration. As we have seen, the warmth of the body is due to the combination of the oxygen received through the lungs with certain materials derived from our food. Animals with highly

developed lungs, using an abundance of air, are warm blooded and need much food to supply the wastage. Others, such as snakes, with partially developed lungs, and fishes with gills, using very small amounts of oxygen, are cold blooded and need but little food. All who have ever kept a canary bird and a gold fish, not differing greatly from each other in weight, must have noticed the amount of food required in the two cases.

Second, oxygen is necessary for all forms of ordinary combustion. Without fire civilization would have been impossible. At the present time we are able to do much by the application of water power to electric generators, but without fire primitive man could never have made such a machine. Without fire he would never have been able to smelt the various metals from their ores; could never have made his steel tools; there would be no steam railways, steamships, nor any of the conveniences of modern civilized life; in short, he must have remained in the barbarism of the stone age.

Third, oxygen is now used frequently in a medicinal way. The pulmotor is a familiar appliance in every hospital for use in cases of drowning, asphyxiation, electric shock, etc., to induce artificial respiration. After explosions in mines and buildings, or in smouldering fires, the oxygen helmet enables the rescuing parties or firemen to go where they otherwise could not and is often thus the means of saving human life. Again in crises of disease, oftentimes, where there is great weakness, air enriched with oxygen, given artificially often sustains the patient till the greatest danger is passed.

7. **Oxygen and Health.**—When the nerves of the human body are exposed to the air from any cause as in the case of a burn or wound of any sort, it is prob-

ably the action of the oxygen that produces the pain. The logical suggestion, therefore, after cleansing the wound, or if it be a chemical burn, after treating with the proper antidote to remove all traces of the offending agent, is to protect from the air by some such material as olive oil or by some of the other equivalent methods of modern nursing. In all cases the exclusion of the air is effected. From this and from the fact that oxygen is usually necessary in decay and decomposition, it might be thought that oxygen has a harmful as well as a useful side. Such is hardly the case, however. We have already seen how polluted waters are purified. So also is the air. From time immemorial foul gases of all sorts have been escaping into the air, sufficient, ages ago, to render it unfit for respiration, had they not been destroyed. But the oxygen is ever combining with these, so that under ordinary conditions the air is as pure and fresh today as it was in the time of man's infancy. Moreover, were it not for the disintegrating action of oxygen upon all waste matter, refuse of every sort, the accumulation long ago would have been beyond human endurance. So, while in occasional cases from its very nature oxygen may cause the exposed nerve to smart and tingle, its values to health are so beyond all comprehension that we can think only of its beneficent side.

8. **Kindling Temperature.**—By kindling temperature is meant the temperature at which a substance takes fire or begins to burn. In the oxygen experiments mentioned above the sulphur and phosphorus needed very little heat to ignite them, while the iron had to be well kindled and even then began to burn with some difficulty. Yellow phosphorus has perhaps the lowest kindling temperature of any substance with which most

of us are familiar, in that very little friction is amply sufficient to ignite it. Sulphur and paraffine are a little higher, paper and wood somewhat higher, and so on. To show that the kindling temperature of paper is considerably above the boiling point of water, a very simple, interesting experiment may be made. Fill an ordinary paper, sanitary drinking cup about one-third full of water and suspend it on a ring stand as shown in Fig. 12. Place a Bunsen burner under it with the flame playing directly upon the cup, but not lapping up over the sides. In a few minutes the water will boil vigorously. It is better if a cup not coated with paraffine can be used as its kindling temperature is much lower than that of paper and sometimes the drops of melted wax that run down will become scorched. The paper, however, remains unburned.

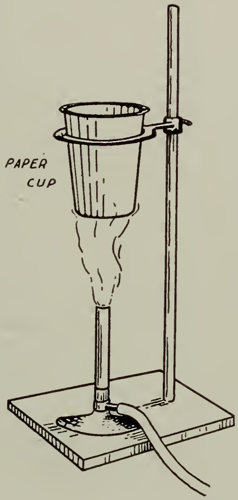


Fig. 12.—Boiling water in paper cup.

9. **Oxidation and Spontaneous Combustion.**—When-

ever any substance combines with oxygen the process is called oxidation, although to the chemist the term has a broader meaning. It may be slow or rapid: if sufficiently rapid to produce light and perceptible heat, it is called combustion. This often takes place spontaneously. If a small piece of yellow phosphorus is dissolved in carbon disulphide and poured upon a filter paper upon a ring stand, within a very few seconds after the liquid has evaporated sufficient heat is produced by the slow oxidation of the minute particles of phosphorus spread over the paper to ignite it spontaneously and the whole bursts into flame. Likewise, certain oils, especially linseed, in waste or rags, soon begin to oxidize; the heat accumulates till often, after some hours, the kindling temperature is reached and the mass begins to burn. All waste of an oily character, therefore, should be thrown into air-tight metal cans to be kept there until disposed of in some safe manner. Again, it is common at coal mines to see the dump on fire. This is brought about spontaneously. In such cases there is usually more or less iron pyrite present, which becoming wet by the rains begins to oxidize, whereby sufficient heat is generated to set on fire the small amounts of coal contained in the refuse from the mine. The same thing occasionally happens in coal bins especially on ship-board where the amount stored is large and the ventilation poor so that the heat tends to accumulate.

Exercises for Review

1. Name the two discoverers of oxygen with dates of their work.

2. What names were given to oxygen at first? Why so given? Why called oxygen?

3. About what part of the world does oxygen form?

4. State briefly how oxygen is distributed in nature.

5. What method may be used for obtaining oxygen from water?

6. What did the original discoverers use in making oxygen?

7. What is the best way of preparing oxygen abundantly?

8. What is a catalyst? Catalytic action? Illustrate.

9. What four experiments with oxygen can you give?

10. What is the main purpose of these experiments?

11. Name seven characteristics of oxygen.

12. Of what value is the free oxygen found in water?

13. Name three important uses of oxygen; what are the medical uses?

14. What is the action of the oxygen upon foul gases? Upon waste matter?

15. What is meant by kindling temperature. Give four illustrations.

16. How may it be shown that the kindling temperature of paper is not low?

17. Define oxidation; combustion.

18. What is the explanation of spontaneous combustion? Illustrations?

CHAPTER VI

OZONE AND HYDROGEN DIOXIDE

Outline—

1. Allotropic Forms of Elements.
    - (a) Oxygen and Ozone.
    - (b) Diamond and Graphite.
    - (c) Yellow and Red Phosphorus.
2. Characteristics of Ozone.
3. Ozone in Nature, Produced How.
    - (a) By Slow Oxidations.
    - (b) By Electrical Discharge in Air.
4. Preparation in Class Room.
    - (a) By Slow Oxidation of Phosphorus.
    - (b) In Preparing Oxygen from Potassium Permanganate.
5. Practical Uses.
    - (a) In Sterilizing City Water Supplies.
    - (b) In Purifying Air for Public Buildings.
    - (c) In Cleansing Wheat for Milling.
6. Hydrogen Dioxide—Commercial Forms.
7. Characteristics.
8. Uses.
9. Test for Ozone and Peroxide.

Exercises for Review.

Ozone

1. **What Is Ozone?**—There are several of the elements which occur in nature in more than one form. Thus, the diamond and graphite, both familiar to every one, the latter in the so-called lead pencil, are two very dissimilar forms of carbon. In the study of oxygen two

forms of phosphorus, red and yellow, have been seen, one of which is kept under water, while the other needs no such protection. So, ozone is but another form of oxygen. The term *allotropic* is often used in such cases, and the less common form is called the *allotrope.* Thus ozone would be an allotropic form or allotrope of oxygen. In cases where one is about as common as the other each variety may be spoken of as the allotrope of the other. Ozone is really condensed oxygen, three volumes being condensed into the space of two. Thus 60 volumes of oxygen would, if it all could be made into ozone, form only forty volumes. However, ozone is very unstable and is constantly changing back into the common form; hence, after a relatively small portion of any volume of oxygen has been converted into ozone, the process becomes reversible at a speed not differing greatly from the direct action and the quantity of ozone from that time on will not materially increase.

2. **Characteristics of Ozone.**—Ozone has a peculiar odor, somewhat irritating if strong. It was through its odor that it was discovered, the name being derived from a Greek word, meaning *to emit odor.* It is always noticeable about strong electrical discharges, hence in x-ray work, wireless telegraphy, and similar operations, the air always becomes heavily charged with this allotropic form. It is much more active than ordinary oxygen, attacks the throat and bronchi if inhaled deeply and tarnishes quickly various metals such as silver and mercury which remain unchanged in the air.

3. **Ozone in Nature.**—Ozone is produced during all electrical storms and for some unknown reason in slow oxidations. It is strongly germicidal and in this way is valuable in nature in purifying the air. It is possible

that some of the valuable uses of oxygen in nature already mentioned, may be due to the more active allotropic form of ozone.

4. **Preparation.**—Sufficient ozone to give a good test may be obtained by allowing a stick of freshly scraped yellow phosphorous to remain partly exposed, for a few minutes, to the air in a closed bottle. Another easy method for obtaining sufficient quantities to be decidedly noticeable by the odor is to dissolve about a half gram of potassium permanganate in about ten cubic centimeters of water and add cautiously two or three cubic centimeters of strong sulphuric acid.

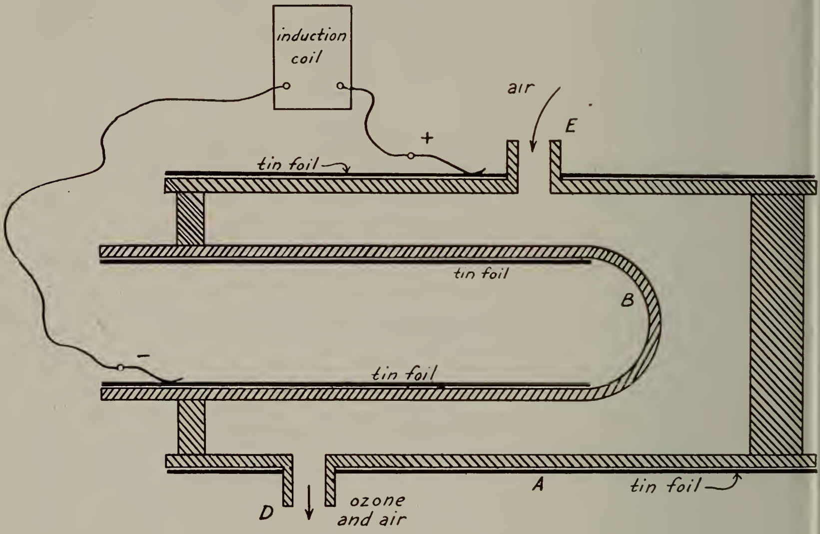


Fig. 13.—Machine for making ozone.

5. **Practical Uses of Ozone.**—In many of the cities of Europe, especially of France and Russia, ozone is used in purifying the water supplies, just as has been mentioned chlorine is in America. It is said that one gram of ozone, which would be about one pint, is sufficient

to destroy 30,000 pathogenic bacteria per cubic centimeter in 250 gallons of water. To make this statement clear, let it be said that 250 gallons, roughly speaking, is 1,000 liters, which equal 1 million cubic centimeters. So, with 30,000 bacteria per cubic centimeter, one gram of ozone would have the power of destroying 30,000 million bacteria, like those of cholera or typhoid. Ozone is also being used in many theatres and picture shows and similar places for the purpose of purifying the air. By the systems of ventilation it is pumped into the room along with the streams of fresh air. Theoretically the plan seems valuable but in practice there seems some doubt as to its efficacy. Ozone is also used in some large flour mills to destroy any traces of smut or must that may not have been removed by the processes preliminary to milling. Fig. 13 illustrates one type of ozonizer used in obtaining the ozone used for the purposes just mentioned. The current of air enters at *E* and leaves at *D; B* is a glass tube lined on its inner surface with tin foil; *A* is a larger tube, also of glass, covered on its outer surface with the same metal; the binding posts of an induction coil are connected with these two tin foil coatings. The electric current spreads over the surface of one, and being of high voltage, passes through the space from *A* to *B* in a brush discharge so that practically all the enclosed air is subjected to the condensing effects of the electricity.

Hydrogen Dioxide

6. **What Is Hydrogen Dioxide?**—To the public, hydrogen dioxide is sold in a diluted form of about 3 per cent under the name of Dioxygen, or Hydrogen Peroxide. Thus diluted, it is not different from water in

appearance; more concentrated, it is thicker and somewhat sirupy. In composition it differs from water in that it contains twice as much oxygen. In the electrolysis of water it was found that the volume of hydrogen obtained was twice that of the oxygen; were the same experiment possible with hydrogen dioxide the volumes of the two gases would be the same.

7. **Characteristics of Hydrogen Dioxide.**—In the concentrated form it is very unstable, the extra volume of oxygen being rapidly set free. In the diluted commercial forms this same process is going on but very slowly. It has a slight odor and a peculiar taste. It is strongly germicidal due to the oxidizing effects of the *nascent* oxygen being evolved at all times.

8. **Uses.**—Being a mild germicide, yet at the same time effective, and perfectly safe even in the hands of the least skillful, it has wide application in this way. It is also an excellent bleaching agent for such animal products as hair, wool, silk, feathers and ivory and has extensive use for some of these.

9. **Test for Hydrogen Dioxide.**—A few drops of dioxygen if added to about ten cubic centimeters of starch mucilage or thin paste in a test tube together with a very little of potassium iodide solution gives the whole a beautiful deep blue color. The same test applies for ozone except that a strip of white paper must be dipped in the starch-iodide solution and suspended in the atmosphere of ozone. The starch on the paper turns blue.

Exercises for Review

1. What is ozone?
2. What is an allotrope? Name several.
3, What relation in density between ozone and oxygen?

4. Give two ways by which ozone is produced in nature.

5. Give two methods of making ozone in the class room.

6. What are the most striking characteristics of ozone? Compare it with ordinary oxygen.

7. What three practical uses for ozone are suggested? State the efficacy in one of these uses.

8. How is the ozone obtained for these commercial uses?

9. Compare hydrogen dioxide and water in composition.

10. Give four characteristics of hydrogen peroxide.

11. What two important uses has hydrogen peroxide? For what is it a good bleaching agent?

12. Give a good test for ozone and hydrogen dioxide with results.

CHAPTER VII

COMMON SALT AND SODIUM

Outline—

1. Abundance of Salt.
    (a) Found in the Blood.
    (b) In the Ocean.
    (c) In Salt Lakes.
    (d) In Mineral Deposits.
2. Methods of Obtaining.
    (a) Evaporating Water from Lakes and Sea.
    (b) Evaporating Brine from Deposits.
    (c) Mining Rock Salt.
3. Characteristics of Salt.
4. Uses of Salt.
    (a) As a Preservative.
    (b) In Food.
    (c) In Refrigeration.
    (d) In Manufacturing Other Sodium Compounds.
5. Composition of Salt.
    (a) Determined by Electrolysis.
6. Discovery of Sodium.
7. Its Manufacture.
    (a) Description of Apparatus.
8. Properties of Sodium.
    (a) Chemical.
    (b) Physical.
9. Uses of Sodium.

Exercises for Review.

1. **Abundance of Salt.**—We have already studied two familiar substances, water and air. Another almost as familiar to us is common table salt, known to the chemist by the name of sodium chloride. It is

found almost everywhere: in the dust particles in the air, in the blood, .8 of one per cent, in the ocean and salt lakes, in many mineral springs, in immense deposits in the earth. If a Bunsen burner is lighted in a room which has just been swept, it will be noticed that the flame is yellow from the dust particles: this is due to the sodium chloride present, for sodium compounds always color a flame yellow as we saw when we were studying hydrogen. In the ocean the water is about 2.8 per cent common salt—an amount estimated at over 35,000 billion tons. Some one has calculated that if the ocean averaged 1,000 feet in depth everywhere, the common salt contained would in bulk equal 3,500,000 cubic miles. As this is probably a low assumption as to average depth, the actual salt contained would if piled up in mountains surpass in size and grandeur some of the great chains of our western Rockies. Deposits of great thickness exist at various places; four states, New York, Michigan, Ohio, and Kansas, furnish about 90 per cent of that made in the United States. At one place in the last named state the deposits are said to be 300 feet in thickness and of most excellent quality. Smaller amounts are produced by California, Utah, West Virginia, Louisiana, Oklahoma, Texas and Pennsylvania. In California are one or more lakes of considerable extent with a crust of nearly solid salt, somewhat impure, six or eight inches in thickness during the dry season of the year, upon which one can walk with perfect safety. These lakes appear like one in our northern climates frozen over at a very windy time with snow falling so that the surface is left very rough.

2. **Methods of Obtaining.**—In Utah the water is pumped from Salt Lake into shallow pools some distance away and

evaporated by the sun. The quality of salt is perhaps not of the best but may be used in many ways. In California considerable salt is made from San Francisco Bay: the water is pumped into pools and evaporated. In some states a portion of the salt is mined as is coal; most of this is put on the market in the form of rock salt either for use of cattle or crushed for refrigeration mixtures. In most of the salt-producing states, holes are drilled down into the salt layer, water is run down and allowed to stand until saturated and is then pumped out through an adjacent hole. This method gives a brine much more concentrated than that obtained from the ocean or bay; it is run into an evaporating pan and heated till one of the impurities, calcium sulphate, usually present, on account of its being less soluble, separates out. Then the solution is run into a second pan and the concentration continued.

3. **Characteristics of Common Salt.**—In small quantities salt is not harmful; in fact it is deemed necessary in the animal economy as furnishing the means of providing the hydrochloric acid in the stomach. In large amounts it becomes even toxic in its action, and in China it is said that it is often used as a means of committing suicide. Upon the lower organisms it is always destructive and its preservative qualities depend upon this fact. Most people have the idea that table salt is hygroscopic, but magnesium chloride, an impurity found in most salt deposits to an amount of nearly four-tenths of one per cent of the whole is the cause of the trouble. To prevent table salt from becoming damp in rainy weather some manufacturers mix with it a small amount of starch or prepared chalk or even cooking soda: this coats the salt grains containing the impurity so that they can not take up the mois-

ture from the air. Analysis of the various samples of table salt on the market show a content of sodium chloride ranging from 97 to 99 per cent.

4. **Uses of Salt.**—The uses of salt are most too common to need mention. A very considerable portion of that manufactured is used in the preservation of meats and meat products: in seasoning the food of the nation about eleven pounds per capita of table salt is used every year, while the total quantity employed in various ways reaches 30,000,000 barrels. Mixed with ice as a freezing mixture, salt is also used very extensively. It is also the starting point for several very valuable compounds, which will be studied elsewhere.

5. **Composition of Salt.**—We have spoken of salt as sodium chloride. To prove this is not difficult. One of the best methods is that of electrolysis as was used in the case of water. A U-shaped tube, as shown in Fig. 14, is filled with salt water to which has been added a few drops of a solution of phenolphthalein in 50 per cent alcohol. Electrodes are inserted, after determining which way the current is flowing, and within a few seconds the solution at the negative pole is turned reddish violet in color, while if means be taken to collect the gas evolved there it will be found to be hydrogen. Further experiment will show that sodium hydroxide has been formed in this tube and it was this which gave the color to the phenolphthalein. At the positive electrode a gas of very offensive irritating odor is given off which later will be shown to be chlorine. This experiment may now be repeated using a salt solution colored blue with litmus: no change will be apparent at the cathode, but at the anode where the chlorine is being produced the blue color is rapidly

bleached. Again if the salt solution colored blue with litmus have a drop of hydrochloric added to make the solution red and the current then be passed, at the cathode where the sodium hydroxide is forming the solution becomes blue caused by the hydroxide, while the other arm is quickly bleached as before. The student will understand why the sodium is not apparent at the cathode as the chlorine is at the anode if he refers to the work in hydrogen. It will be remembered that sodium in contact with water rapidly decomposes it, setting free hydrogen. So here the sodium particles as fast as formed at the cathode attack the water, producing sodium hydroxide and hydrogen.

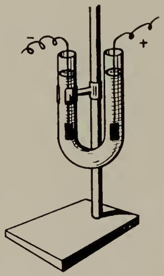


Fig. 14.—Electrolysis of salt in water.

6. **Discovery of Sodium.**—For some years previous to 1807 sodium hydroxide had been regarded as an elementary substance. It was left to Sir Humphrey Davy to prove that it was a compound of sodium. By fusing the compound and passing a current of electricity through it he obtained the silvery metal at the cathode.

7. **Its Preparation.**—At the present time sodium is manufactured by the same plan suggested by Davy. Changes have been made in the apparatus, as a commercial plant must always differ from a laboratory model, but the principle is the same. Fig. 15, illustrating what is now known as the Castner process, will

show the method. A large metal vessel usually of iron, marked *V* in figure, contains the caustic soda to be melted; through the bottom of this is inserted a bundle of carbon rods which serve as the cathode; another vessel, *W*, which forms the anode, is inverted over the larger one and dipping into the melted caustic; in the center, over the cathode, is a collecting pot, *P*, closed at the bottom by a coarse wire gauze which readily permits the passage of the melted caustic. When the soda has been melted by the application of heat the current is switched on; oxygen collects on the anode and bubbles out; sodium and hydrogen, both being positive, collect on the carbon rods and rise into the collecting pot. The hydrogen is allowed to escape and when somewhat cooled the sodium is dipped out and poured into moulds.

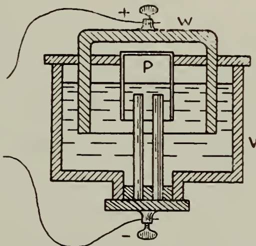


Fig. 15.—Preparation of sodium.

8. **Properties of Sodium.**—As already stated after potassium, sodium is the most electropositive of all the metals. It is silver white in color, almost as soft as putty, melts at 95.6° C., has a specific gravity of 0.97, which means it is just a little lighter than water; heated somewhat, it burns in chlorine, producing common salt; likewise it will burn in oxygen or the air, forming sodium peroxide, corresponding to hydrogen peroxide, which has been mentioned elsewhere under

the name of "oxone;" it reacts vigorously with cold water, violently on hot, with the formation of hydrogen and sodium hydroxide. Naturally, therefore, in the air, always more or less moist, it is rapidly tarnished; first sodium hydroxide is formed and later, by the absorption of the carbon dioxide, sodium carbonate. In the laboratory it is kept in bottles covered with some oil containing no oxygen, like benzine or kerosene. On wet blotting paper, not being able to roll around as on water, it quickly melts, and if dropped to the floor as it is about to catch fire, it bursts into many small globules, burning with a yellow flame as they roll off in every direction.

9. **Uses of Sodium.**—In the chemical laboratory there are a number of uses for sodium; also for the manufacture of a variety of complicated organic compounds, like artificial rubber; but its characteristics do not admit of any extensive general uses.

Exercises for Review

1. What can you say of the distribution of salt upon the earth?
2. Name the best salt-producing states.
3. From what sources is salt obtained in various locations of the United States?
4. Give three ways of obtaining salt. Which is the more common?
5. Of what value is salt in the human economy?
6. What causes table salt to become damp? How is this sometimes prevented?
7. Name some valuable uses for salt.
8. What is the composition of salt? Give method of proof.
9. Who was the discoverer of sodium? How was it made?
10. Describe process of manufacturing sodium now.
11. Describe sodium.
12. How is sodium kept in the laboratory?
13. What uses has sodium?

CHAPTER VIII

CHLORINE AND THE HALOGEN FAMILY

Outline—

1. Names of the Halogens.
    - (b) General Characteristics.
2. Historical Points of Chlorine.
    - (a) Discoverer and His Ideas of Chlorine.
    - (b) His Name for It; Reasons.
    - (c) Humphrey's Work and Name Suggested.
3. Preparation of Chlorine.
    - (a) In Laboratory.
    - (b) Commercial Method.
4. Description of Chlorine.
    - (a) General.
    - (b) Combustion Experiments.
    - (c) Physiologic Effects.
    - (d) Gas Masks.
5. Uses of Chlorine.
    - (a) For Bleaching.
    - (b) Sterilizing Water Supplies.
    - (c) In the Sick Room.
    - (d) In Gas Warfare.
6. Hydrogen Chloride.
    - (a) Historical.
    - (b) Method of Preparing.
    - (c) Description of.
7. Hydrochloric Acid.
    - (a) Historical.
    - (b) What it is.
    - (c) Characteristics.
    - (d) Value of.
8. Aqua Regia, What? and Uses.

9. Iodine.
    (a) Discovery.
    (b) Sources of Supply.
    (c) Preparation and Purification.
    (d) Description of.
    (e) Uses.

Exercises for Review.

1. **The Halogens.**—The word *halogen* means *salt producer.* It is given to a group of four elements the general characteristics of which are very similar and which form a large number of compounds closely resembling common salt. They are fluorine, chlorine, bromine and iodine with atomic weights respectively of 19; 35.46; 78.92; and 126.92. The first two are gases, the third a liquid and the fourth a solid. They all have an irritating odor, somewhat similar, but differing in intensity, that of iodine being feeble. They all have great chemical activity, but in the inverse order of their atomic weights, fluorine being very much more active than iodine. In the present chapter we shall study only the chlorine and iodine.

2. **Some Historical Facts of Chlorine.**—Chlorine was discovered by Scheele in 1774; it will be remembered that the year previous he prepared oxygen from manganese dioxide. Chlorine he obtained from the same oxide by treating it with strong hydrochloric acid in which experiment he thought the oxygen contained in the manganese dioxide had combined with the acid. Therefore, in the terms used in his day he named it *dephlogisticated marine acid air,* which in our day would mean oxidized hydrochloric acid gas. So Scheele did not know he had discovered a new element in chlorine, and his idea was shared by other chemists for considerably over a quarter of a century, until Sir

Humphrey Davy proved it to be an element and suggested the name it now has.

3. **Methods of Obtaining Chlorine.**—The usual plan in the laboratory is that used by Scheele, and a convenient form of apparatus for use is shown in Fig. 16. The manganese dioxide is put into the flask, the cork and thistle tube inserted and when everything is ready, the hydrochloric acid is added. The method of collecting the gas is called *downward displacement* and is the one commonly used when a gas is heavier than air and soluble in water.

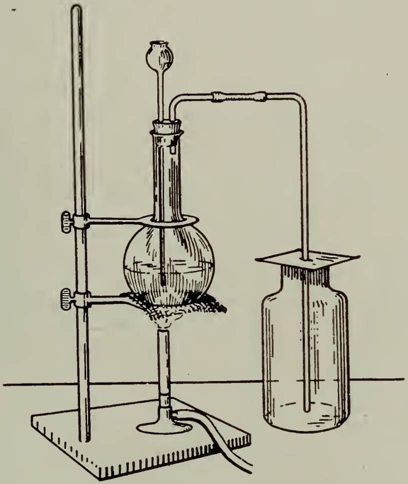


Fig. 16.—Preparation of chlorine in the laboratory.

Commercial Methods of Manufacture.—Several patents have been taken out for preparing chlorine on a large scale by the electrolysis of a saturated solution of common salt. In the preceding chapter in studying the composition of salt we have seen a laboratory plan of making the experiment; the commercial apparatus seeks to keep separate the products formed and use all of them, in order to cheapen the process. One type of these machines is shown in Fig. 17. The bundle of carbon rods in the central compartment which contains water serves as the cathode; an anode is inserted into each of the other compartments, which contain the saturated brine; a layer of mercury covers the bottom and serves as a seal between the two outer and the central compartments. The chlorine is set free at the anodes and is drawn off there; the sodium on being repelled toward the cathode meets the mercury and dissolves in it. By means of an eccentric, *E* in figure, the trough is continually rocked so that the mercury containing the sodium comes into contact with the water in the central compartment where the usual effect takes place with the formation of sodium hydroxide and the evolution of hydrogen. It will be seen therefore that by this process three products are obtained at the same time.

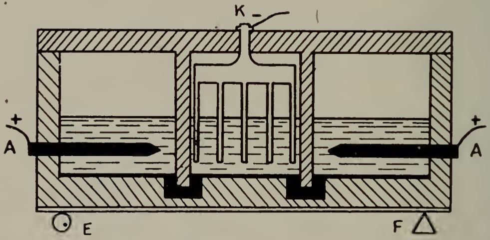


Fig. 17.—Manufacture of chlorine.

4. **Characteristics of Chlorine.**—The term chlorine is from a Greek adjective meaning green and was suggested for this gas because of its greenish yellow color. It is about two and a half times as heavy as air, will not burn in the air, but in it a large number of substances will burn, most of them taking fire spontaneously. Nearly all the metals, if finely powdered and sifted into chlorine, burn with a shower of sparks.

Several other metals, malleable in character, if rolled into thin foil and lowered into a bottle of chlorine take fire the same way. Sodium must be heated, but when this is done it burns in chlorine producing a white solid which is common salt. Phosphorus lowered into chlorine is ignited almost instantly; turpentine, heated to near its boiling point, and placed in chlorine on a strip of blotting paper burns with a copious volume of dense, black smoke and a dull red flame which disappears when all the turpentine has been decomposed. The paper does not catch fire as its kindling temperature is above that of the burning hydrogen; and really it is only the hydrogen that is combining rapidly with the chlorine while the other constituent of turpentine, carbon, is set free to form the dense clouds of black smoke. From these experiments we see that combustion may take place in the absence of oxygen and with other substances. We must, therefore, broaden our ideas regarding it and define it as the union of *any two* substances with such rapidity as to produce heat and light. A burning jet of hydrogen inserted into a bottle of chlorine continues to burn as well as in the air; in reality it burns with much more vigor.

At ordinary room temperature chlorine will liquefy under seven atmospheres' pressure; or, at –33° C. it becomes a liquid at one atmosphere pressure. In the liquid form it is of a beautiful golden yellow color, and may be kept in a strong glass tube hermetically sealed. At lower temperatures it becomes a white solid, resembling snow, which changes to yellow as it melts. It is soluble in water, two volumes to one, hence can not be collected over water without considerable loss of gas. It has a very irritating odor, attacks the throat, bronchi and lungs, and if much is inhaled causes intense suffering and ultimately death. There is no known satisfactory antidote: ammonia mixed with air or the fumes of alcohol if inhaled afford some relief. The gas mask used by the soldiers in case of gas attacks owes its efficiency to the use of sodium thiosulphate or to a very porous charcoal made from nut shells or both, through which the air must pass before being inhaled. These substances absorb and retain the chlorine so that it does not reach the individual.

5. **Uses of Chlorine.**—One of the most extensive uses of chlorine is for bleaching. Practically all cotton and linen goods are bleached by this means, also much of the paper pulp for white paper. Many of the larger flour mills throughout the middle west and possibly elsewhere treat the flour with chlorine to render it whiter than it would be otherwise. It is also used in all large steam laundries to impart the excessive whiteness now demanded by a too critical public: the result is a much shortened life of all white goods sent to the laundry.

By experiment it will be found that chlorine does not bleach any substance if perfectly dry. Moisture must be present. The explanation is that chlorine does not do the work directly, but when brought into contact with water a reaction takes place, forming hydrochloric and hypochlorous acids. The latter compound is very unstable and rapidly breaks up setting free oxygen. It is this nascent or atomic oxygen that does the work. It will be seen, therefore, that the process is really one of oxidation. That oxygen is really set free can be shown by a very simple experiment, illustrated in Fig. 18. The test tube shown is entirely, and the evaporating dish partly, filled with water which has been saturated with chlorine in a room not very light. It is then placed in a window in bright sunlight, whereupon bubbles of gas will be seen collecting in the upper part of the tube. If tested with a pine splinter in the usual way it will be found to be oxygen.

As previously stated chlorine either in the liquid form or as a calcium compound is used in the sterilizing of city water supplies. It is a powerful disinfectant. The compound of chlorine and lime known as bleaching powder, is valuable in sick rooms. A spoonful or two in a saucer of water gives off slowly free chlorine: the quantity is not sufficiently great to be noticeable except close to the dish yet it has a very beneficial effect upon the air. Moreover, it is very cheap, and is sold commonly under the name, chloride of lime. Chlorine is also extensively used in the extraction of gold from its ores.

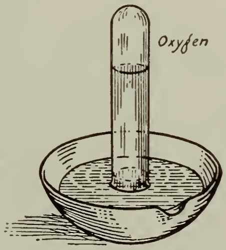


Fig. 18.—Effect of sunlight on chlorine water.

It may be said, further, that chlorine was the first of the poisonous gases to be used in warfare. Steel cylinders, containing liquid chlorine, the wind blowing toward the English and French troops and the ground sloping in the same direction, were opened: the pressure being relieved, the liquid was with very great rapidity converted into a gas and flowed down hill in great greenish-colored waves. Later gas bombs and various other devices as well as other poisonous gases were used.

6. **Hydrogen Chloride.**—Under the name, *spirit of salt,* and later, *marine acid air,* this compound has been known to the chemist for several hundred years, possibly since the middle of the fourteenth century. The easiest way of obtaining it is to treat common salt with strong sulphuric acid and heat gently.

Characteristics of Hydrogen Chloride.—It is a colorless gas, of very irritating odor, heavier than air, will not burn or cause other substances to burn. In solubility it ranks next to the highest of the common gases: one liter of ice cold water will dissolve 600 liters of hydrogen chloride. Putting this in other words, a liter being about a quart, and 600 quarts being 150 gallons or three large barrels, one quart of ice water will dissolve three of our largest sized barrels of the gas under one atmosphere of pressure. If the breath is blown across the top of a tube or flask generating hydrogen chloride, copious white fumes are seen; the explanation is that the moisture has been removed from the breath by the gas and has been condensed as tiny drops, just as is the case in a fog. At –80° C. it becomes a colorless liquid, like water, which has little or no effect upon metals as long as no water is present.

7. **Hydrochloric Acid.**—Hydrochloric acid is a solution of hydrogen chloride in water. At 20° C., which is about the ordinary temperature of a room, a liter of water will absorb about 450 liters of hydrogen chloride and give a solution containing about 36 per cent of the gas. This is sold as strong hydro-

chloric acid. The term *muriatic*, is more often applied to the impure variety, yellow in color, due to the presence of small quantities of iron chloride, and other impurities. If strong hydrochloric acid is boiled, it constantly becomes weaker until the solution contains 20 per cent of the gas after which it remains constant. If a weak solution is boiled, the water evaporates the faster until a strength of 20 per cent is attained.

Uses of Hydrochloric Acid.—A century ago hydrogen chloride was a waste product from the sodium carbonate factories of England and France. Being heavier than air, and soluble in water, tall chimneys made to carry it away, were of little avail. In the absence of wind it settled to the ground, rendered the air irrespirable, and killed vegetation all about the factories. Brought down by rain it attacked all tools and most metal objects exposed. Attempts were made to carry it away in streams, but here it killed the fish and other aquatic animals. Finally, stringent laws compelled the manufacturers to seek the aid of chemists in devising uses for a worse than troublesome gas. So successful were their efforts that in solution now hydrogen chloride is one of the most valuable and most extensively used of any of the acids. In fact, wherever the old method of making sodium carbonate is still followed it is solely for the purpose of the acid obtained, while the soda crystals have become the by-product. There is scarcely any factory or industry which does not use more or less hydrochloric acid. In the stomach, it has already been mentioned, hydrochloric acid plays an important part in digestion. The reason some animals can so readily digest bones which they imperfectly masticate and swallow is that their digestive fluids contain a large amount of hydrochloric acid which readily dissolves the mineral matter from the bones and then the animal portions are digested about as so much gelatin would be.

8. **Aqua Regia.**—The words "aqua regia" mean *royal water* and are applied to a mixture of hydrochloric acid with nitric in the proportions of three of the former to one of the latter. They are so used because the mixture is an excellent solvent for gold and for a considerable time was the only good solvent known for the king of metals. The solvent power is due to the evolution of chlorine. This chlorine, as is the case with the oxygen from hydrogen peroxide, ozone, or in bleaching by chlorine, is in the nascent or atomic state, and is exceptionally active. The reason for this can be seen if it be remembered that unlike elements unite chemically. However, if no element positive in character is present for union with the chlorine atom, it, being unable to exist alone, combines with another chlorine atom and forms the molecule. Aqua regia is also the best solvent for platinum as well as some other metals. It always produces a chloride when it dissolves a metal. This would necessarily be so if it is the chlorine which does the work.

9. **Iodine.**—This halogen was discovered by Courtois in 1811. In heating the ashes of sea weeds he noticed a beautiful violet vapor which was found to be the gaseous form of an element hitherto unknown. It rereceived its name from a Greek word meaning *violet.*

Source of Supply.—For a good many years all the iodine used was obtained from kelp, a species of sea weed; but at the present time most of the supply comes from the saltpeter beds of Chile where it exists as sodium iodate, mixed in very small amounts with the sodium nitrate.

Preparation and Purification.—If chlorine is bubbled into a solution of an iodine compound, as sodium iodide, the chlorine, being more electronegative, combines with the sodium and releases the iodine. This is shown by the solution assuming the color of iodine tincture. From this it may easily be distilled out and collected in a suitable condenser; this is the method employed in France for the preparation of iodine, whether from seaweed ashes or other source. Another method, that of treating the iodine compound with manganese dioxide, and sulphuric acid and distilling out the iodine, is more often employed in Great Britain. By any method certain impurities are present which are removed by sublimation. This means the distillation of a solid which does not melt on heating, but changes directly into vapor. The process will be understood from Fig. 19. Each conical shaped condenser receives the sublimate from the preceding.

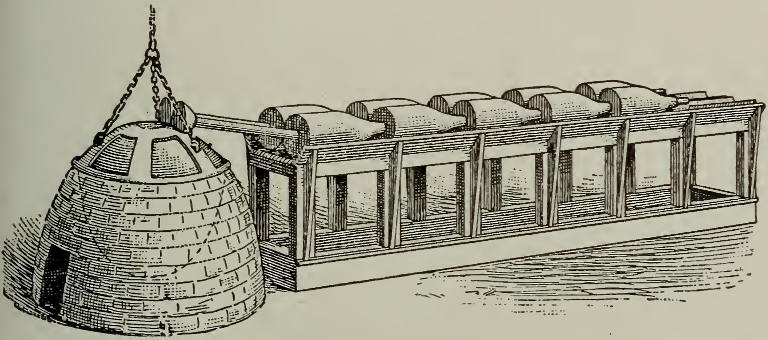


Fig. 19.—Iodine apparatus.

Characteristics.—Iodine is a crystalline solid, lustrous as a metal, nearly black in color, which gives off vapors even at ordinary temperature, violet in color. It has an odor resembling chlorine but much weaker and less irritating. It combines with many of the metals readily. A crystal of iodine laid upon a thin slice of yellow phosphorus reacts with it vigorously with sufficient heat produced to set the phosphorus on fire in a few seconds. It is but slightly soluble in cold water, a little more so in hot, while in a solution of potassium iodide in water it dissolves readily. Alcohol, chloroform, carbon disulphide and ether are all fine solvents. With starch paste or mucilage, a dilute solution of iodine gives a beautiful blue color. This is the usual test for it and is a very delicate one, one part of iodine being perceptible in several hundred thousand of water.

Uses of Iodine.—The main use of iodine is for medicine in the form of tincture, which is an alcoholic solution. This is used as a counterirritant in case of swellings, inflammation, etc., also as an antiseptic in surgical operations, accidental wounds, and the like. It is stronger and more penetrating than hydrogen peroxide hence sometimes preferable, but it is also more severe. In iodoform, a light yellow solid of rather peculiar and disagreeable odor, it is also often used as an antiseptic. An extract from the thyroid body of sheep, known as iodothyrin, is given medicinally as a stimulant to the development of the same organ in the human body.

Exercises for Review

1. Name the halogens and state how they received the name.
2. Give their more common characteristics.
3. Who discovered chlorine? What was his idea about it?

4. Who proved it to be an element? Why did he name it chlorine?

5. What is the usual way of preparing and collecting chlorine?

6. Describe briefly a commercial method of making chlorine.

7. Give the effects of chlorine upon several metals and other substances.

8. How does it compare with oxygen in chemical activity?

9. What is the effect if inhaled? Antidotes?

10. Explain how the gas mask prevents injury.

11. Name four kinds of substances bleached commercially by chlorine.

12. Explain how chlorine bleaches. What other agent have we studied which bleaches the same way?

13. Give some medical use for chlorine; also two other important uses.

14. Mention two old names for hydrogen chloride. Why so named?

15. How is it prepared?

16. What are the chief characteristics of hydrogen chloride?

17. Illustrate its great solubility.

18. What is hydrochloric acid? Muriatic acid?

19. Mention some of the annoyances of hydrochloric acid gas a century ago.

20. What can you say of its value now?

21. What is aqua regia? It uses? Why does it make chlorides always?

22. When, by whom, and how was iodine discovered?

23. Give two sources of our commercial supply of iodine.

24. What two ways of preparing iodine can you mention?

25. What is sublimation? How different from distillation?

26. Describe iodine. What are the best solvents?

27. What is tincture of iodine? Its uses?

28. What is iodoform, iodothyrin? Their uses?

CHAPTER IX

GASES AND SOME GAS LAWS

Outline—

1. States of Matter.
2. Effects of Heat on Matter.
    - (a) On Solids and Liquids.
    - (b) On Gases.
3. Charles' Law.
    - (a) Statement and Illustrations.
    - (b) Absolute Zero.
4. Correction of Gas Volumes for Temperature Changes.
    - (a) Standard Temperature.
    - (b) Working Formula.
5. Effect of Pressure upon Gases.
6. Boyle's Law.
    - (a) Statement of.
    - (b) Demonstration of.
    - (c) Formula for Pressure Corrections.
7. Pressure Readings.
    - (a) How Taken.
    - (b) Aneroid Barometer.
8. Temperature and Pressure Corrections.
9. Practical Applications of These Gas Laws.
10. Deductions from These Laws.
    - (a) Matter Not Continuous.
    - (b) Molecular Theory.
    - (c) Gas Pressures Due to Molecular Motion.
    - (d) Atomic Theory of Dalton.
    - (e) Avogadro's Hypothesis.
11. Atomic Weights.
12. Molecular Weights.

Exercises for Review.

1. **States of Matter.**—All are familiar with the fact that matter exists in three states,—solid, liquid and gaseous. Many substances exist in all three. Ice becomes a liquid on the addition of heat, and at a still higher temperature changes into a gas. So do paraffin and a large number of other familiar substances. Others, however, before they reach a point at which they would melt, are decomposed into other and simpler compounds.

2. **Effects of Heat.**—The first effect of heat upon practically all substances is that of expansion. This is true whether it be a gas, a liquid or a solid. In the case of liquids and solids, the rate of expansion is exceedingly variable, no two substances being exactly the same. Gases, on the contrary, behave alike, so that certain laws regarding them have been discovered which apply to all.

3. **Charles' Law.**—When a volume of gas at 0° C. is heated it is found to expand $1/273$ of its volume for every degree heated. That is, if we had 273 c.c. of hydrogen or any other gas in a vessel at 0° C. and warmed it to 1° C. the volume would become 274 c.c.; if we heated it ten degrees, the volume would be 283 c.c.; if it were cooled ten degrees, the volume would be 263 c.c. In the briefest form these facts are stated in what is known as Charles' Law: "The volume of any gas, provided the pressure is constant, varies uniformly with the temperature." From what has been said in illustration, if the supposed volume of 273 c.c. were cooled to 100 degrees below zero it would decrease 100 c.c.; if cooled 273 degrees would entirely disappear. It is unbelievable by any one that by removing heat from a body we could cause it to disappear or cease to exist. The truth is, that all

substances liquefy or solidify before reaching any such temperature as – 273° C., and thereafter the law does not apply to them, for the rate of expansion and contraction of solids and liquids is exceedingly small as compared with that of gases. The temperature of – 273 degrees of centigrade, however, is known as absolute zero, for reasons that will be explained later; and while no thermometer of this name is manufactured, it is often necessary to use the *absolute scale*, hence the comparison of it with the centigrade is shown in Fig. 20. The freezing point of water, zero centigrade, is 273 absolute; boiling water, 100 C., is 373 absolute, etc.

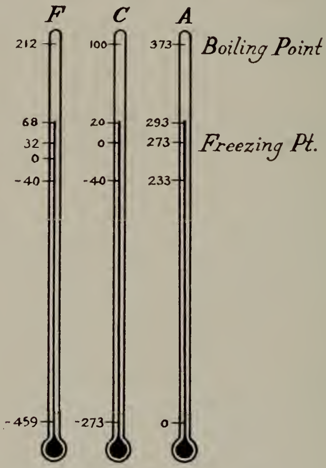


Fig. 20.—Comparison of thermometers.

4. **Correction of Volume Readings.**—Because of the great difficulty of weighing a gas, the quantity is usually expressed in volume; but as changes in temperature cause such great variation in volume, some temperature must be taken as a standard to which all vol-

umes are referred. The freezing point of water, being easy to determine, the centigrade zero, has been adopted and is often spoken of as the *standard temperature.* Suppose we have 500 c.c. of oxygen in a tank at 20° C. and wish to know its volume at 30°. According to Charles' Law it would increase $^{10}/_{273}$ of the volume it occupied at 0° C., but we only know its volume at 20°. We make use of this proportion in all such cases:

$$V : V' :: T : T'$$

or, what is more convenient, the equation derived from the proportion,

$$VT' = V'T$$

in which V is the original volume, V′ the new volume, and t and t′ the original and new temperatures centigrade, respectively. Substituting in this equation we have,

$$500 \times (273 + 30) = V' \times (273 + 20)$$

If $t =$ temperature centigrade, and T, absolute,

$$T = 273 + t.$$

It will be noticed that we have used absolute thermometer readings, which must always be done in making corrections for temperature changes. Keeping this in mind, Charles' Law is more accurately stated thus: "The volume of a gas, pressure remaining constant, varies directly as the *absolute* temperature." By solving the above equation the value of V′ will be the true volume of the gas at the new temperature.

5. **Effect of Pressure upon Gases.**—It was thought for many years that liquids and solids could not be compressed: it is known now that they may be, though

but slightly. Furthermore, in undergoing pressure as was the case in heating them they are variable and obey no law. Gases, however, as on heating, behave alike, a fact discovered by Robert Boyle, already spoken of as the father of Physics and Chemistry.

6. **Boyle's Law.**—Briefly stated, this law is, "The volume of any gas, temperature remaining constant, varies inversely as the pressure." This means that if we have 500 c.c. or any other volume of gas in a closed vessel to which we can apply pressure, and then double the original pressure the gas will be reduced to half its original volume. Likewise if we removed half the pressure the gas would double in volume. This may be shown in what is known as a Boyle's Law apparatus, shown in Fig. 21. The short end of the tube is closed and enough mercury poured in to fill the bend as shown. As the mercury level is the same in both arms, the pressure upon the two surfaces must be the same. Upon the open end the weight of the air is resting, hence there must be one atmosphere's pressure upon each surface. Now pour into the open end more mercury, sufficient to double the original pressure. The volume of the gas in the closed space is decreased to half what it occupied at the beginning. As the atmospheric pressure varies greatly from day to day, so the volume of any gas will vary; it is often necessary, therefore, to make correction for pressure as was done for temperature changes. For such purposes, Boyle's Law is expressed in the form of a proportion:

$$V : V' :: P' : P$$

in which V and V' are the original and new volumes, respectively, and P and P' the corresponding pressures.

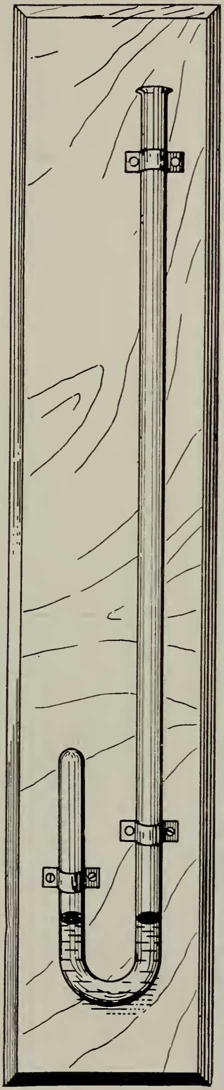


Fig. 21.—Boyle's Law Apparatus.

For solving problems the proportion is better used in the form of an equation, thus:

$$VP = V'P'$$

7. **Barometer Readings.**—Probably all are familiar with the fact that atmospheric pressures are obtained by the barometer; but these readings are usually given

Fig. 22.—Aneroid barometer.

in inches or millimeters and not in weight. We say that the barometric pressure was 29 inches when we mean that the pressure was equal to the weight of a certain column of mercury 29 inches high. But we destroy no mathematical relation when we substitute inches for weight and we save the calculation each time of the weight of that much mercury. In scientific calculations millimeters are commonly used instead of inches, 760 millimeters being the equivalent of 30 inches. On account of convenience in handling, an aneroid barometer, shown in Fig. 22, is often used instead of a mercurial, and gives corresponding readings. Let us illustrate by a problem. Suppose we have 500 c.c. of gas at 760 mm pressure and desire to know the volume at 740 mm. Substituting in

$$VP = V'P'$$

we have

$$500 \times 760 = V' \times 740$$

from which the new volume is easily found.

8. **Temperature and Pressure Corrections.**—In the discussion of Charles' and Boyle's Laws above, each was said to be true when the third factor is constant. That is, the volume varies directly as the absolute temperature if the pressure does not change; and the volume varies inversely as the pressure provided the temperature does not change. Usually, however, both pressure and temperature vary. For such cases a combined formula is used,

$$VPT' = V'P'T$$

in which the letters mean as in the preceding cases. Let us apply it in a problem. Suppose we want to know what the volume of 1,000 cu. ft. of natural gas measured at 20° C. and 750 mm. pressure, would be at 30° C. and 720 mm. pressure. Substituting in the formula,

$$1{,}000 \times 750 \times (273 + 30) = V' \times 720 \times (273 + 20)$$

from which the value of V′ is easily found.

9. **Practical Value of These Laws.**—There are many ways in which these laws find practical application in modern life. The balloonist must take them into consideration when he fills his bag. If he puts too much gas in, when he ascends into a clearer and dryer air, the heat of midday may tend to produce such expansion of the gas contained as to burst the bag. If he puts in too little, the contraction upon cooling after dark may be sufficient to bring the balloon to the earth. Again in every city these laws apply in the case of the gas used for fuel and lighting. Most city ordinances specify that the gas shall be furnished at a pressure not under that of a certain number of inches of water pressure, say six or eight: now, if the gas company pumps gas through the mains at a pressure less than that specified, according to Boyle's Law, the volume would be increased, but there would be no more heat units in the greater volume at 4 inches pressure than in the smaller volume at 8 inches pressure: yet the meter would charge up the larger amount. It is obvious that gas should be sold not by volume but by number of heat units contained.

10. **Deductions from These Laws.**—When a given volume of gas is compressed, its weight remains constant; likewise, cooling or heating a gas does not change its weight. By modern apparatus it is possible to apply to a gas a pressure of 10,000 atmospheres whereby it is reduced to $1/_{10,000}$ of the volume it originally possessed. There is only one conclusion that can be reached from such facts and that is that gases are not made up of *continuous* matter but of separate particles which

may be crowded much closer together. And as all gases behave alike under the same changes in conditions, this must be true of all gases. While we are here considering only gases, it might be interesting to inquire whether the same is true of liquids and solids. If 500 c.c. of alcohol and a like volume of water are poured together in a graduated cylinder at first without mixing as shown in Fig. 23, and are then thoroughly stirred, it will be found that the volume is no longer 1000 c.c., but about 900 c.c. If a certain weight of salt is dissolved in 100 c.c. of water, it will be found that the new volume is but slightly above 100 c.c., and not nearly that of the water and salt originally. Into a liter of ice water we may pass several hundred liters of a hydrogen chloride gas before the water becomes saturated, and the gas all disappears without very greatly increasing the volume. Years ago attempts were made to compress water and other liquids in metallic globes and it was found that invariably upon flattening the

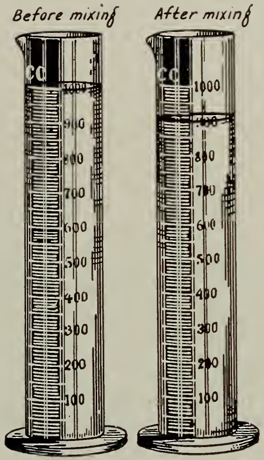


Fig. 23.—Contraction of volume on mixing two liquids.

globe and thereby reducing the volume, the liquid was forced *through* the metal and appeared in tiny drops upon the outside. A few years ago an Englishman, Sir Roberts-Austen, placed some cylinders of lead upon sheets of gold and allowed them to remain for four years. At the end of that time he found by testing the lead that there were gold particles in it as far up as eight millimeters. These and many other experiments all tend to show that liquids and solids as well as gases consist of matter *not absolutely continuous.*

The Molecular Theory.—All scientists now accept the theory suggested above, that matter is not continuous, but is made up of minute particles which they call *molecules.* The word, derived from the Latin, means a *small mass.* In solids these molecules are close together; in liquids, somewhat farther apart, while in gases they are at very great distances relatively. For instance, the average distance of one molecule from another in a gas at ordinary temperature and pressure is vastly greater than that of the earth from the moon in proportion to the diameters of the bodies considered. For example, the diameter of the earth is about 8,000 miles; the moon is distant from the earth about 240,000 miles or about thirty times the diameter of the earth. A more accurate comparison would be that of the various planets of the solar system from each other and from the sun. A bottle "full" of hydrogen might be spoken of as a vacuum with a "few" particles or molecules of hydrogen in it at relatively great distances from each other. So, when we compress a gas 10,000 times, we have not merely moved the moon up to the earth, a distance 30 times the diameter of the earth, but 10,000 times that distance, or relatively, 10,000 × 8,000 which is 80,000,000 miles, a distance nearly that of the earth from the sun.

In solids, Lord Kelvin has shown conclusively, the distance from the center of one molecule to that of the next one is not less than $\frac{1}{500}$ millionth of an inch and not more than $\frac{1}{250}$ millionth of an inch. Cubing 500 millions would give the possible number of molecules in a cubic inch, or cubing 250 millions, the least number there could be. Some one has estimated that to count the molecules lying in a row one inch long at the rate of one per second would require 23 years of 300 days each and ten hours a day!

Molecules in Motion.—Not only is matter composed of molecules but these tiny masses are at all times in motion. There is much evidence of this. Dust particles, no matter how small, have no inherent power of motion and sooner or later all settle. Not so molecules: regardless of how little gas there may be in any closed space it is always evenly distributed and gives the same pressure at all points. Gases are also capable of indefinite expansion: if half the gas in a receiver be removed by an air pump, the remainder expands till it occupies the whole space; and this continues indefinitely. In the study of the air we have already spoken of diffusion. It can be explained in no other way and means nothing else than that the molecules of the various gases constituting the air are in constant motion.

Gas Pressures.—It is the constant bombardment of the molecules of a gas in a closed space that produces the pressure; if half the gas has been removed by means of an air pump the manometer will show only half the pressure that it did at the beginning. This is because there are only half as many molecules now to bombard a given area as at first and the pressure is correspondingly decreased. Likewise if we pump a gallon of air into a bicycle tire which already contained a gallon we have doubled the number of molecules; there will be twice as many impacts per second now as formerly and the gauge will show double the pressure it did before.

The Atomic Theory.—The theory that matter is composed of molecules satisfies most of the phenomena dealt with in the study of physics, but the chemist needs something more. John Dalton, who died in 1844, recognizing this fact, suggested what is now known as the atomic theory. Briefly stated it is this: molecules are composed of still smaller particles, called atoms, a word derived from the Greek, meaning *not able to be divided:* second, that the atoms of each element have a certain, definite weight; third, that this weight is different from that of every other element; and fourth, that chemical union takes place between the atoms of elements and not between larger masses. Roughly put, this last statement means that nature furnishes us matter tied up in packages of different kinds having a certain definite weight, and when we unite them to form compounds, we must do so by using one package, or two, or more as may be needed. This hypothesis, offered so many years ago, seems to explain and be sufficient for all the laws of combination so far as it applies.

Avogadro's Hypothesis.—In 1811, Avogadro, an Italian physicist, formulated the hypothesis which still bears his name. It is: ''Equal volumes of all gases under the same conditions of temperature and pressure contain the same number of molecules.'' No absolute, experimental proof can be offered, hence we do not often speak of it as a *law;* but it explains a large number of observed facts not otherwise understood, is in violation of none, and is undoubtedly true.

11. **Atomic Weights.**—According to Dalton's atomic theory, the individual atoms have certain definite weights. Obviously, one atom is too small to be weighed, hence we can assign only relative values. As hydrogen is the lightest of all gases, seemingly, one atom of this element should be our unit. Accordingly the hydrogen atom was assumed to have a weight of *one* and to this unit weight was given the name *microcrith;* and the weights of the other elements were compared to this; that is, oxygen being about sixteen times as heavy as hydrogen would have an atomic weight of 16, and so on for the other elements. It was found, however, that if the weight of the hydrogen atom was assumed as one microcrith, the comparative weights of a very large number of the other elements differed considerably from whole numbers, but if the hydrogen atom is assumed as weighing 1.008 microcriths, oxygen then becomes *exactly* 16 and a very large number of the other elements have atomic weights either whole numbers or very nearly so. On account of the advantage this fact has in chemical calculations it has been accepted as preferable. The atomic weight of any element, therefore, is the weight of an atom of that element in microcriths, on the assumption that an atom of oxygen weighs 16 microcriths or the hydrogen atom, 1.008 microcriths.

12. **Molecular Weights.**—The molecular weight of a substance is the sum of the weights of the atoms constituting a molecule of that particular substance. Thus, we have found that water contains two parts hydrogen to one of oxygen, by volume. Later it will be

shown that a molecule of water contains two atoms of hydrogen and one of oxygen: adding the weight of two atoms of hydrogen to that of one atom of oxygen and omitting the decimals we have 18 as the molecular weight of water. The complete table of atomic weights of the elements will be found on page 283.

Exercises for Review

1. What three states of matter? How changed from one into another? Why do not all substances thus change?

2. What is the primary effect of heat upon all substances? How are gases different from other substances?

3. Give Charles' Law and illustrate.

4. What is meant by absolute zero? What would 0°C. be on absolute scale? 20°C? 100°C.? –23°C? –73°C?

5. What is meant by standard temperature?

6. A gas has a volume of 680 c.c. at 0°C. What would be its volume at 10°C.?

7. State Boyle's Law. Illustrate.

8. What is meant when we say the pressure is 28 inches? What is the equivalent of 30 inches in millimeters? Reduce 28.5 inches to millimeters.

9. When temperature and pressure both change, what formula must be used?

10. Give some practical application of these two laws.

11. How do you explain the fact that a gas can be compressed so much, and a solid so little? Illustrate.

12. Give some proofs that matter is not continuous in solids: in liquids.

13. State briefly the molecular theory. Give some idea of the size of the molecule.

14. What can you say as to the distance of gas molecules from each other?

15. What proof can you give that molecules have motion?

16. What is the cause of the pressure on the inside of an automobile tire?

17. If a tack pierces an automobile tire which showed on the gauge a pressure of 80 pounds and air escapes till the gauge only registers 20 pounds what part has escaped?

18. State the points in Dalton's atomic theory.

19. State Avogadro's Hypothesis.

20. What is meant by atomic weight? By a microcrith? Illustrate.

21. What is meant by the molecular weight of a substance? Illustrate.

CHAPTER X

SYMBOLS AND FORMULAS

Outline —

1. Origin of Symbols.
2. Symbols.
    - (a) Consist of What?
    - (b) Exact Meaning of.
3. Formulas.
    - (a) Consist of What?
    - (b) Represent What?
    - (c) Structural Formulas.
4. Radicals.
    - (a) Consist of What?
    - (b) Represent What?
5. Chemical Equations.
    - (a) Description of.
    - (b) How Read.
    - (c) Equality of.

Exercises for Review.

1. **Origin of Symbols.**—In olden days in order to render their notes unintelligible to any chance reader, the alchemists used many signs and hieroglyphics to represent their mixtures. Later it seemed highly desirable that some brief method of representing elements and compounds and the various chemical changes which took place should be adopted. Hence from an old practice with no system for its foundation has grown a method of symbolization, exact as any branch of mathematics, and valuable in the extreme in many ways, at the same time intelligible to every chemist the world around.

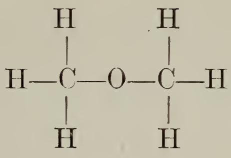
2. **Symbols.**—A symbol represents a single atom of an element. This is necessarily so as the atom is the unit in all chemical changes. The symbol of an element is its initial letter, or, as sometimes there are several elements beginning with the same letter, the initial letter and some other prominent letter in the word. In case two letters are used, the second is a small letter; the first is always a capital. It is important to remember this as confusion may result otherwise. Thus, C represents carbon; O, oxygen; Co, cobalt, a metal resembling iron; CO, carbon monoxide; a compound body. So, many other illustrations might be given where there would be room for doubt. Sometimes the Latin name is used as a derivation for the symbol: especially is this true of those elements discovered and studied at a day when it was believed that the Latin language was the only one to endure for all time. Thus Ag is the symbol for silver, from *argentum;* Pb is for lead, from *plumbum;* Au for gold, from *aurum.*

3. **Formulas.**—As a symbol represents a single atom of an element, so a formula indicates a molecule of some substance. A formula is a combination of symbols and usually represents a molecule of a compound, though in its simplest form it may stand for a molecule of an element. Thus, H_2 which is a shortened form of HH is a combination of two symbols and represents a molecule of hydrogen: likewise, OOO, written O_3, means a molecule of ozone and As_4 a molecule of arsenic. Generally, however, the formula applies to a compound and shows not only what elements enter into the compound, but the amounts also. If more than one atom of an element is contained in a molecule of the compound that fact is indicated in the formula by placing

a small figure at the right and a little below the symbol for that particular element. Thus, H_2SO_4 represents a molecule of sulphuric acid which contains 2 atoms of hydrogen, one of sulphur and four of oxygen. Again, $Al_2(SO_4)_3$ represents a molecule of aluminum sulphate, which contains two atoms of aluminum, three of sulphur and twelve of oxygen, the figure 3 outside of the parenthesis multiplying everything enclosed therein. If it is desired to represent more than one molecule of a compound body, it is done by using a coefficient. Thus, $5H_2SO_4$ means five molecules of sulphuric acid. Obviously, and this is important to remember, the coefficient multiplies each symbol in the formula. This is necessarily so, since, if there are four atoms of oxygen in one molecule of sulphuric acid, there would be five times as many in five molecules. The same would be true of the hydrogen and sulphur.

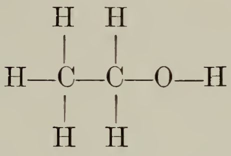
Structural or Graphic Formulas.—Sometimes it is highly desirable to show the arrangement of the atoms in a molecule. Especially is this true in the study of carbon compounds where we may have two with the same empirical formula but with widely different properties. Thus methyl ether and ethyl alcohol have the same empirical formula, C_2H_6O, usually written $(CH_3)_2O$ and C_2H_5OH, that they may be easily distinguished and to show that one is an oxide and the other a hydroxide. Such compounds as these are said to be *isomeric,* from two Greek words meaning *of equal parts.* The two compounds are not at all alike in properties: the only way we can explain this is that the atoms are not linked together in the same manner. Structural formulas seek to make plain the method of linkage, thus:

Methyl Ether



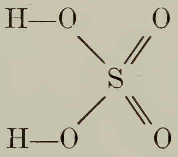
$$\begin{array}{ccccccccc} & & H & & & & H & & \\ & & | & & & & | & & \\ H & — & C & — & O & — & C & — & H \\ & & | & & & & | & & \\ & & H & & & & H & & \end{array}$$

Ethyl Alcohol



$$\begin{array}{ccccccccc} & & H & & H & & & & \\ & & | & & | & & & & \\ H & — & C & — & C & — & O & — & H \\ & & | & & | & & & & \\ & & H & & H & & & & \end{array}$$

In sulphuric acid the atoms are linked thus:



4. **Radicals.**—More often the term radical means a combination of symbols which represent a group of elements forming a part of a compound, but which can not exist alone. Thus in all sulphates we find the group, SO_4, but no such compound exists. We can prepare SO_2 and SO_3, but not SO_4. Moreover, such groups give individual tests as if they were single elements. Thus, any sulphate in solution would contain the group SO_4 and will always give a white precipitate when barium chloride solution is added, just as sodium chloride or any other chloride in solution does with silver nitrate. A few of the more common radicals are NH_4, found in all ammonium compounds, as NH_4NO_3, NH_4Cl; NO_3 in all nitrates, as KNO_3,$NaNO_3$; CO_3, in all carbonates, as K_2CO_3, Na_2CO_3, $CaCO_3$; PO_4 in phosphates, K_3PO_4; Na_3PO_4; ClO_3 in all chlorates, $KClO_3$; HO, in hydroxides, as KHO, NaHO. Each one of these groups gives some

special test just as oxygen will ignite a glowing pine splinter.

5. **Equations.**—The student is familiar with algebraic equations which are entirely abstract. In chemistry an equation means much more. It is simply a short method of indicating the chemical change which has taken place in some experiment. The left-hand side indicates the substances used and the right hand, the products obtained. More than this, the exact amount of each is shown and as nothing can be lost, destroyed or gained in any chemical change, the sum of the amounts of the substances used must equal the sum of the weights of the substances obtained. However, as chemical change causes the destruction of a *particular* substance and the formation of new ones, the elements entering into the change will not be arranged as they were at the beginning. To illustrate: In studying water we passed a current of electricity through it and obtained two gases, hydrogen and oxygen, both of which we tested to be sure as to what they were, with the volume of the former twice that of the latter. Expressing this chemical change in the form of an equation, we have

Water (electrolyzed) yields Hydrogen
(2 parts) and Oxygen (one part)

Or, using symbols and formulas to make it briefer,

$$H_2O \rightarrow H_2 + O$$

Now a molecule has been defined as the smallest portion of matter which can exist alone. It is known that a molecule of oxygen contains two atoms, hence in the equation just written we have shown a half molecule of oxygen which can not exist; hence it is customary to write this equation thus:

$$2H_2O \rightarrow 2H_2 + O_2$$

It will be noticed that the sign → is used instead of the equality and is read *yields* or *produces* or in some similar way. Again, in studying hydrogen, we prepared the gas from water by the use of sodium. Thus,

Sodium and Water produce Hydrogen and Sodium Hydroxide.

As must always be done we tested the products to know exactly what was obtained. To use symbols and formulas, this becomes,

$$2Na + 2H_2O \rightarrow H_2 + 2NaHO$$

and, Zinc and Sulphuric Acid give Hydrogen and Zinc Sulphate;

$$Zn + H_2SO_4 \rightarrow H_2 + ZnSO_4$$

If any of the equations given are studied, it will be observed that everything found upon the left side is also upon the right. Thus, in the sodium and water, the two parts of sodium of the left are found in the sodium hydroxide on the right: the four atoms of hydrogen in the water, on the right side are, two of them in the free molecule of hydrogen and the other two in the two molecules of sodium hydroxide, while the two atoms of oxygen in the water are found in the two of hydroxide on the right. Such is always the case.

Exercises for Review

1. Who were the first to use chemical symbols and what was their purpose?

2. Of what does a symbol consist? What kind of letter or letters are used?

3. Why is the observance of this last fact important?

4. Give five symbols from the Latin.

5. What is a formula? What does it represent?

6. How is the number of atoms in a molecule expressed in a formula?

7. How many atoms of each element in alum, $K_2Al_2(SO_4)_4 24H_2O$?

8. Give exact amount of each in $Na_2CO_3 10H_2O$.

9. What is the usual meaning of the term radical? Illustrate

10. Which of those given is positive? Which negative? How do you know?

11. What does a chemical equation represent? Explain fully.

12. Change the following into chemical formulas and symbols:
    - a. Electrolysis of water.
    - b. Burning hydrogen in the air.
    - c. Exploding hydrogen in a pistol.
    - d. Passing hydrogen over red-hot copper oxide.
    - e. Exploding hydrogen in the eudiometer.
    - f. Putting sodium on water.
    - g. Heating mercuric oxide.
    - h. Heating potassium chlorate.
    - i. Heating potassium chlorate mixed with manganese di oxide.
    - j. Burning charcoal in oxygen.
    - k. Burning hydrogen in chlorine.

CHAPTER XI

OXIDES, ACIDS, BASES, AND SALTS

Outline —

1. Oxides.
    - (a) Abundance of; What?
    - (b) Classes of—Basic. Acidic.
    - (c) Reaction of Each with Water.
2. Bases and Alkalies.
3. Anhydrides and Acids.
4. Nomenclature of Bases.
5. Nomenclature of Acids.
6. Acids.
    - (a) Physical State of.
    - (b) Familiar Examples.
7. Salts and Neutralization.
    - (a) Classes of Salts.
    - (b) Nomenclature of Salts.
    - (c) Binary Salts.

Exercises for Review.

1. **Oxides.**—In the preceding chapters we have met with a number of oxides; from mercuric oxide Priestley prepared oxygen; Scheele made the same gas from manganese dioxide; this same oxide was used as a catalyst in connection with potassium chlorate for making oxygen; it was used again with hydrochloric acid in making chlorine. When studying oxygen, various substances, as sulphur, charcoal, phosphorus and iron were burned in the gas; in each case an oxide of the corresponding element was obtained. An oxide is a compound of two elements one of which is oxygen. As

oxygen combines with all the commoner elements except fluorine there are a very large number of oxides: they may be divided into two classes according to the compound each forms when it reacts with water. When Lavoisier suggested the name "oxygen" he believed that the product formed by oxygen with any element was an acid and for many years a large number of oxides were accordingly called acids.

2. **Classes of Oxides.**—When electropositive elements like sodium, potassium, calcium and the like unite with oxygen one class of oxides is produced and when the electronegative, like sulphur, phosphorus, etc., another class is obtained. The first are known as *basic* oxides and the second as *acidic*. The reasons for this will be seen later.

3. **Reaction of Water upon Basic Oxides.**—If such oxides as sodium oxide and others named above as basic are put with water a reaction takes place as shown by the following equations:

$$Na_2O + H_2O \rightarrow Na_2H_2O_2 = 2NaHO$$
$$K_2O + H_2O \rightarrow K_2H_2O_2 = 2KHO$$
$$CaO + H_2O \rightarrow CaH_2O_2 = Ca(HO)_2$$

The product formed in each case is a hydroxide, the positive part of which is the metal, while the negative part is common to all, the *hydroxyl* radical. These and many other similar compounds are called *bases,* hence the oxides from which they were derived were spoken of as basic oxides, or base-forming oxides. Not many bases may be formed directly from the action of water upon the corresponding oxides because not many oxides are soluble in water, hence no reaction is possible.

4. **What Is a Base?**—All bases are *hydroxides,* as seen above. A base may be defined as a compound containing the negative radical hydroxyl, and if soluble in water, turns red litmus blue and has a soapy, somewhat bitter taste. Only a few bases are soluble in water. In addition to those named already may be added barium hydroxide, $Ba(HO)_2$; strontium hydroxide, $Sr(HO)_2$; and ammonium hydroxide, NH_4HO. All such soluble hydroxides are called *alkalies* and they all attack the skin to a greater or less extent, hence some of them are spoken of as caustic; thus, sodium hydroxide is often called caustic soda.

5. **Reaction of Water with Acidic Oxides.**—When such oxides as those of phosphorus, sulphur and the like are passed into water the reaction is shown by the following equations:

$$SO_2 + H_2O \rightarrow H_2SO_3$$
$$SO_3 + H_2O \rightarrow H_2SO_4$$
$$CO_2 + H_2O \rightarrow H_2CO_3$$
$$P_2O_5 + 3H_2O \rightarrow 2H_3PO_4$$

The product in each case is an acid instead of a hydroxide. All the main chemical properties are essentially different from the compounds obtained above in Section 3. The positive part of these compounds is hydrogen as will be found by putting a metal with them, in that the more positive metal will expel the hydrogen. These compounds are called *acids* and the oxides which produced them, acidic oxides as already mentioned. A very considerable number of acids may be produced directly by adding the oxide to water but not nearly all. Such oxides as these are commonly called *anhydrides.* Defining, we would say that an anhydride, or as some call them, an acidic anhydride, is an oxide which will form an acid on the addition of water, or more briefly, an anhydride is an acidic oxide.

6. **Definition of an Acid.**—It is not an easy matter to define an acid. It is a compound whose positive part is hydrogen and if soluble in water will turn blue litmus red and has a sour taste. As most acids are derived from oxides either practically or theoretically they usually contain oxygen as a part of the negative radical; but hydrochloric and several others we may meet with, not being derived from oxides, contain no oxygen.

7. **How Bases Are Named.**—It was stated early in the study of compounds that in naming them we always give the electropositive part first. Hence as the positive part of such compounds, generally speaking, is a metal, we give the name of this and then as the negative part is hydroxl, we add that. Thus,

+	−	+	−
Sodium	hydroxide	Na	HO
Calcium	hydroxide	Ca	$(HO)_2$
Copper	hydroxide	Cu	$(HO)_2$
Ammonium	hydroxide	NH_4	HO

It will be noticed that the last named base does not contain a metal: it is the only exception we shall meet with; but the group, NH_4, has many of the properties of a metal, one of which is its power of forming a hydroxide.

8. **How Acids Are Named.**—As the positive part of acids is hydrogen, we should expect them to be called hydrogen *something,* as we have called the gas hydrogen chloride before we made a solution of it by passing it into water. From the fact that several of the

commoner acids were discovered and in daily use before any system of nomenclature was adopted, the effort, made later, to apply the system did not meet with favor; hence, we still say

Sulphuric Acid and not Hydrogen Sulphate for H_2SO_4
Carbonic Acid and not Hydrogen Carbonate for H_2CO_3

It is not wrong, however, to use the latter plan, but the common method is to use the name of the nonmetal in the oxide forming the acid and then add the word acid. Thus,

CO_2 is Carbonic Anhydride; with water it forms Carbonic Acid, H_2CO_3
SO_3 is Sulphuric Anhydride; with water it forms Sulphuric Acid, H_2SO_4
P_2O_5 is Phosphoric Anhydride; with water it forms Phosphoric Acid H_3PO_4

As seen, however, some acids contain no oxygen. To emphasize this fact, they all prefix the term *hydro,* thus:

HCl is *Hydro*chloric Acid, while $HClO_3$ is Chloric Acid
HBr is *Hydro*bromic Acid; $HBrO_3$ is Bromic Acid
HI is *Hydr*iodic Acid; HIO_3 is Iodic Acid

Sometimes the electronegative element like sulphur forms more than one oxygen acid, thus:

H_2SO_4	Sulphuric Acid
H_2SO_3	Sulphurous Acid
HNO_3	Nitric Acid
HNO_2	Nitrous Acid
H_3PO_4	Phosphoric Acid
H_3PO_3	Phosphorous Acid

In all these cases, which are typical, it will be noticed that the acid with the smaller amount of oxygen has the ending *ous.*

9. **Familiar Acids.**—Students commonly have the idea that acids are liquids and that most or all liquids found on a laboratory shelf are acids. This is far from the truth. In fact most acids are solids and the greater portion are white crystalline substances. There are a few gases, as hydrogen chloride, fluoride, cyanide (prussic acid): some few are liquids, like sulphuric and nitric; but most are solids. Such are tartaric, citric, lactic, picric and many others.

10. **Salts.**—There is one other class of compounds, very abundant, known as *salts,* because so many of them resemble common salt. To the chemist a salt is a compound formed by the union of a base and an acid. The process is called *neutralization,* because when complete both the base and the acid have lost their characteristic properties; that is, they have had their basic or acidic properties destroyed or rendered neutral. The following equations illustrate the process:

$$NaHO + HCl \rightarrow NaCl + H_2O$$
$$KHO + HCl \rightarrow KCl + H_2O$$
$$Ca(HO)_2 + H_2SO_4 \rightarrow CaSO_4 + 2H_2O$$
$$Mg(HO)_2 + H_2SO_4 \rightarrow MgSO_4 + 2H_2O$$

It will be noticed that in every case water is formed besides the salt. Similar results are obtained if the corresponding basic oxide is used instead of the base, except the amount of water is less:

$$CaO + H_2SO_4 \rightarrow CaSO_4 + H_2O$$
$$MgO + H_2SO_4 \rightarrow MgSO_4 + H_2O$$

11. **Three Kinds of Salts.**—If the neutralization is complete, which is the case when there is one positive

hydrogen in the acid for each negative hydroxyl in the base, the salt formed is a *neutral* or *normal* salt. All of those shown above are of this class. Sometimes there is an excess of hydrogen in the acid over the hydroxyl in the base: in such cases the excess of acid hydrogen remains in the salt formed and gives it some of the properties which the hydrogen had in the acid or of the acid itself and all such are called *acid* salts. Defined, an acid salt is one which contains some of the positive hydrogen from the acid used in making the salt. Thus:

$$2NaHO + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$$
$$NaHO + H_2SO_4 \rightarrow NaHSO_4 + H_2O$$

The second is an acid salt and will turn litmus red in color just as the original sulphuric acid will and the salt also has a sour taste, which is characteristic of acids. It must be observed, however, that not every salt containing hydrogen is an acid salt. The hydrogen must have come from the positive part of the acid to make the salt an acid salt. Thus:

$$NH_4HO + HNO_3 \rightarrow NH_4NO_3 + H_2O$$
$$NaHO + HC_2H_3O_2 \rightarrow NaC_2H_3O_2 + H_2O$$

Neither of these salts is an acid salt, although both contain hydrogen, for the *acid* hydrogen in both cases exactly neutralized the basic *hydroxyl* and left none in the salt.

If the hydroxyl is in excess instead of the hydrogen, then we have what is known as a *basic* salt. Thus, $CuCO_3$ is normal copper carbonate while $Cu(HO)_2CuCO_3$ is a basic carbonate. We shall not meet often with basic salts in our work, hence little need be said here regarding them.

12. **How Salts are Named.**—Normal salts are named as already explained in the study of compounds, that is by reading the name of the positive part of the compound and following this with the name of the electronegative element or group. If the compound is a *binary*, that is, if it contains only two elements, then the ending is *ide*. Thus:

KCl Potassium Chloride
MgO Magnesium Oxide
CuS Copper Sulphide

If the negative part of the compound is a radical group of an acid whose name ends in *ic* the salt name ends in *ate*. Thus:

$KClO_3$ Potassium Chlorate, from $HClO_3$, Chloric Acid
$Mg(NO_3)_2$ Magnesium Nitrate, from HNO_3, Nitric Acid
$CuSO_4$ Copper Sulphate, from H_2SO_4, Sulphuric Acid

We have seen, however, that there are sometimes two anhydrides of the same electronegative element, as for example, sulphur forms both SO_3 and SO_2 each of which forms an acid with water; and each of these acids forms salts with bases. Thus:

$SO_3 \rightarrow H_2SO_4 \rightarrow Na_2SO_4$ Sodium Sulphate
$SO_2 \rightarrow H_2SO_3 \rightarrow Na_2SO_3$ Sodium Sulphite

So, also,

$N_2O_5 \rightarrow HNO_3 \rightarrow KNO_3$ Potassium Nitrate
$N_2O_3 \rightarrow HNO_2 \rightarrow KNO_2$ Potassium Nitrite

It will be seen, therefore, that salts formed from an acid whose name ends in *ous*, have names ending in *ite*.

13. **Acid Salts Named, How.**—Acids which contain

two positive hydrogens can not form *more* than *one* acid salt with any base, hence in reading them we simply prefix the term *acid,* thus:

$NaHSO_4$ is *Acid* Sodium Sulphate or Sodium Hydrogen Sulphate

$KHCO_3$ is Acid Potassium Carbonate, or Potassium Hydrogen Carbonate

Acids which contain *three* positive hydrogens may form *two* acid salts with a given base, in which case it is not sufficient to prefix the term acid, as there are two acid salts. Thus,

H_3PO_4 may form KH_2PO_4 and K_2HPO_4; to distinguish between these we use a prefix designating the number of metallic atoms or groups introduced. Thus, the first of the salts named just above has one potassium atom and this is called *mono*potassium phosphate, while the other is called *di*potassium phosphate.

14. **Binary Salts.**—Binary salts are formed from the acids which contain no oxygen, and all have names ending in *ide* as already stated. However, there may be two of these for any given base: thus, there is Hg_2Cl_2 and $HgCl_2$. In such cases the compound having the greater relative amount of the positive element is called by a name ending in *ous,* in the sense of *full of,* while the other receives the ending *ic.* Thus:

Hg_2Cl_2 is Mercurous Chloride
$HgCl_2$ is Mercuric Chloride
CuS is Cupric Sulphide
Cu_2S is Cuprous Sulphide
FeS is Ferrous Sulphide
Fe_2S_3 is Ferric Sulphide

Exercises for Review

1. What is an oxide? Name five. What was the old idea of oxides?

2. What two classes of oxides are there? Give three examples of each.

3. What is a basic oxide? Why so called?

4. What is a base? Name four with formulas.

5. What is an alkali? Name five with formulas.

6. What is an acidic oxide? Name three. Define anhydride and illustrate.

7. Define an acid. Name two classes and state how different in composition.

8. How are bases named? Give three illustrations.

9. How are acids named? Give three illustrations.

10. How are acids with no oxygen named? Illustrate.

11. Give the names of H_2SO_3, H_2SO_4, HNO_3, HNO_2, H_3PO_4, H_3PO_3.

12. Give the names of HCl, $HClO_3$, HBr, $HBrO_3$, HF, HI, HIO_3.

13. Name two gaseous acids; two liquid; two solid.

14. What is a salt? What is neutralization? Illustrate.

15. What two products always form in neutralization?

16. Name and give illustration of three kinds of salts.

17. Classify each of the following salts: $KClO_3$, $KHSO_4$, K_2CO_3, $NaHCO_3$, K_2HPO_4, KH_2PO_4, KNO_3.

18. How are binary salts named? Illustrate.

19. How are ternary salts named? Illustrate.

20. How are two acid salts from the same acid distinguished from each other?

21. Give names of K_2HPO_4, KH_2PO_4, Na_2HBO_3, NaH_2BO_3.

22. Give names of Cu_2S, CuS, HgO, Hg_2O, $SnCl_2$, $SnCl_4$, As_2O_3, As_2O_5.

23. Classify and give names: KHO, H_3PO_4, H_3PO_3, $Ca(HO)_2$, $CaSO_4$, K_3PO_3, KH_2PO_3, Na_2HPO_4, $HBrO_3$, HBr, $KClO_3$.

CHAPTER XII

AMMONIA AND NITRIC ACID

Outline—

1. Ammonia, Historical.
2. How Obtained—Commercial Supply. Quantities Wasted.
3. Characteristics of Ammonia.
4. Uses of Ammonia.
    - (a) Ammonium Hydroxide in Household.
    - (b) Ammonia Gas in Manufacture of Sodium Carbonate.
    - (c) Ammonia Liquefied for Refrigeration.
5. Nitric Acid.
    - (a) In the Air.
    - (b) Usual Way of Manufacturing.
    - (c) Synthetic Process.
6. Preparation of Nitric Acid.
7. The Oxides of Nitrogen.
    - (a) Names and Formulas.
    - (b) Relation to Nitric Acid.
8. Nitrous Oxide.
9. Characteristics of Nitric Acid.
    - (a) Pure.
    - (b) Commercial Variety.
    - (c) Compared with Other Acids.
10. Uses of Nitric Acid.
    - (a) Making Coal Tar Dyes.
    - (b) Making Explosives.
        - Nitroglycerine.
        - Dynamite.
        - Guncotton, etc.
    - (c) Related Products.
        - Collodion.
        - Celluloid.
        - Fiber Silk.

Exercises for Review.

1. **Ammonia, NH_3.**—Under the name "spirits of hartshorn" ammonia has been known for many years. Even as long ago as the time of Pliny it was known and he speaks of it as the *vehement odor.* It exists in the air in minute quantities, due to the decomposition of certain animal products and other nitrogenous bodies.

2. **Source of Supply.**—Since coal is the result of a metamorphosed vegetation, it contains much nitrogen; hence when soft coal is heated, ammonia is one of the products formed, just as has already been mentioned in cases of slower decomposition. Most of the ammonia of commerce has, therefore, for a good many years been obtained as a by-product in the manufacture of coal gas. The various products from the coal are passed through washers filled with lumps of coke or some similar material or lattice work, kept damp by water dripping over it, whereby the ammonia is absorbed. This is neutralized by dilute hydrochloric or sulphuric acid and ammonia distilled from it by treatment with lime. The following equations show the steps:

$$\text{Coal, heated} \rightarrow \text{Impure ammonia} + \text{other products}$$

$$NH_3 + H_2O \rightarrow NH_4HO \quad \text{(impure)}$$

$$H_2SO_4 + 2NH_4HO \quad \text{(impure)} \rightarrow (NH_4)_2SO_4 \quad \text{(impure)}$$

$$(NH_4)_2SO_4 + CaO \rightarrow 2NH_3 + CaSO_4 + H_2O$$

A vast amount of soft coal is made into coke for the smelting of metallic ores; ammonia and other valuable gases are produced here as in the manufacture of illuminating gas, yet with characteristic American wastefulness only about 20 per cent of this is saved, while the remainder has been allowed to escape into the air. At the same time the United States has been importing fertilizer to the value of millions of dollars when it could all have been supplied from these coke ovens by converting the wasted ammonia into ammonium sulphate as shown by the equations above.

3. **Characteristics of Ammonia.**—Ammonia is a colorless gas with a strong, penetrating odor, producing strangulation and bringing tears to the eyes. In solution it has a bitter, soapy taste and is strongly caustic. It is the most soluble of gases, one volume of ice water being able to dissolve twelve or thirteen hundred volumes of the gas. At ordinary temperatures one liter of water will dissolve about 800 liters, giving a solution containing about 28 per cent ammonia. The gas will not burn in the air nor support the combustion of other substances; it is a little more than half as heavy as air, having a specific gravity of about 0.6. It may be readily liquefied by cold and pressure and in the liquid form boils at –38.5° C. When passed into water the solution which takes place is a chemical one rather than physical, as the equation shows a new product formed,

$$NH_3 + H_2O \leftrightarrows NH_4HO.$$

This new compound, however, is very unstable and the reaction is constantly reversing as shown by the double sign in the equation.

4. **Uses of Ammonia.**—In the form of dilute ammonium hydroxide it is used in the household frequently for cleansing purposes, softening water and other similar ways. In commerce it is extensively used in the manufacture of sodium carbonate by the Solvay process which will be described at another time. It is also used in refrigeration very extensively. For this the

liquefied form is employed as shown in Fig. 24. It is allowed to flow from the containing cylinder into pipes surrounded by brine whose freezing point is not less than –12° C. Surrounded by these pipes are galvanized iron boxes containing the water to be frozen. A pump attached to the ammonia pipes is constantly exhausting the pipes and thereby maintaining a rapid evaporation; it is this evaporation which produces the cold sufficient to lower the brine below the freezing point of pure water. Another pump receives the ammonia drawn from the pipes and compresses it to such an extent that when cooled by water flowing over the condenser pipes it again liquefies and is then ready for use again. It requires about one pound of ammonia to make three pounds of ice, but as the liquid can be used over and over the process of making artificial ice is not an expensive one. Sometimes the brine is pumped

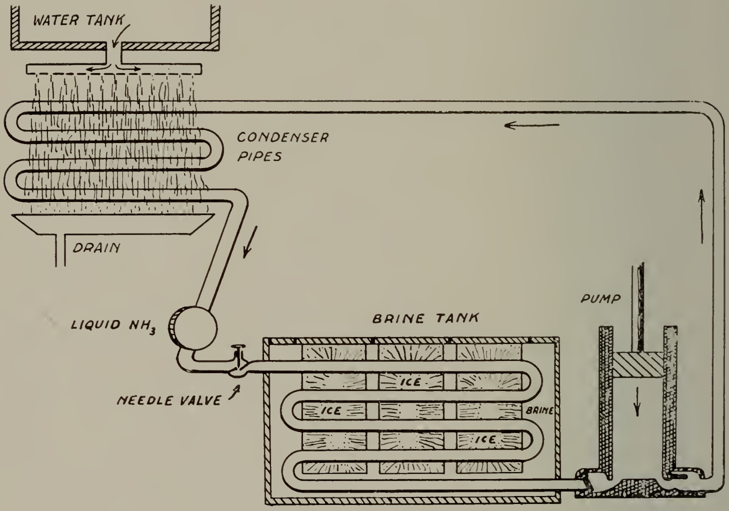


Fig. 24.—Manufacture of ice.

into a second chamber where the water is to be frozen. For cold storage purposes the brine is pumped through pipes into rooms wherever needed so that in markets, floral shops, and various other places pipes, heavily covered with frost, are often seen.

5. **Nitric Acid, HNO_3.**—As nitric acid is an oxyacid, theoretically it would be made from an oxide, its anhydride. In every electrical storm some nitrogen oxides are formed by the union of atmospheric oxygen and nitrogen, and a little nitric acid is produced, therefore, from their solution in the rain. Two or three instances are on record, when the lightning was excessive and the rainfall slight, where the acid was sufficient to give a test. Generally speaking, however, it does not occur free. In the form of compounds it has been very abundant especially in Chile as saltpeter, or sodium nitrate.

6. **Preparation of Nitric Acid.**—In the laboratory nitric acid may be made by distilling a mixture of sodium nitrate and strong sulphuric acid as shown in Fig. 25. If the process is continued long the condenser should be cooled by water. On a commercial scale the same process is employed. The reaction taking place is shown by the equation,

$$NaNO_3 + H_2SO_4 \rightarrow HNO_3 + NaHSO_4.$$

Owing to the limited supply of Chile saltpeter and the difficulty of obtaining it especially in times of war when it is most needed, another process is being rapidly developed now wherever water power may be had. The fact that an electric discharge in the air will produce the anhydride of nitric acid has already been mentioned. This is the principle involved. Where electricity may be had cheaply through water power, the air is forced through chambers where an electric discharge is constantly taking place with the result that one or more of the nitrogen oxides mentioned elsewhere are produced. When these are treated with water, nitric acid is the result.

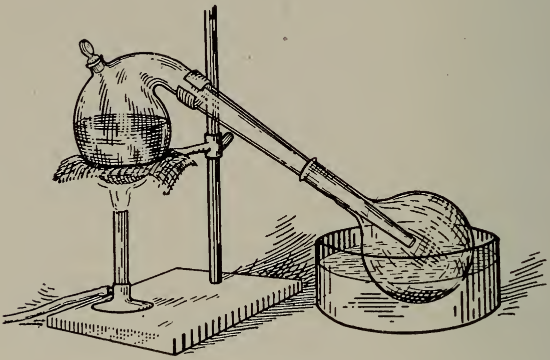


Fig. 25.—Preparation of nitric acid.

7. **Nitrogen Oxides.**—There are five of these oxides, most of them of little interest to the student except for the one fact just mentioned. They are

Nitrogen Monoxide, Nitrous Oxide, N_2O
Nitrogen Dioxide, Nitric Oxide, N_2O_2, usually written NO
Nitrogen Trioxide, Nitrous Anhydride, N_2O_3
Nitrogen Tetroxide, Nitrogen Peroxide, N_2O_4, usually written NO_2
Nitrogen Pentoxide, Nitric Anhydride, N_2O_5

The last three of these may directly or indirectly produce nitric acid on the addition of water, thus:

$$N_2O_3 + H_2O \rightarrow 2HNO_2$$
$$N_2O_4 + H_2O \rightarrow HNO_2 + HNO_3$$
$$N_2O_5 + H_2O \rightarrow 2HNO_3$$

It is thus seen that the first produces nitrous acid alone while the second nitrous and nitric mixed. But nitrous acid is easily changed to nitric by the addition of oxygen so that any one of these three oxides will produce ultimately the nitric acid desired.

8. **Nitrous Oxide, Laughing Gas, N_2O.**—Nitrous oxide is obtained by gently heating ammonium nitrate as shown by the equation,

$$NH_4NO_3 \text{ (heated)} \rightarrow N_2O + 2H_2O$$

The chief interest attached to this gas is its use as an anesthetic. Mixed with oxygen, it is used in minor operations such as tooth extractions or where but little time is needed. It is an intoxicant and has a variety of effects upon different individuals. Ultimately if continued it produces insensibility and death.

9. **Characteristics of Nitric Acid.**—Nitric acid if pure is a perfectly colorless liquid; but in its manufacture some of the oxides of nitrogen especially the peroxide are apt to be present, giving it a brown color. If pure, its boiling point is 86° C. and density 1.56. It is unstable in this form and is put upon the market with a strength of about 68 per cent and a specific gravity of 1.42. Even at this strength heat and bright sunlight decompose it somewhat so that the brown fumes of nitrogen peroxide appear and discolor the liquid. A small addition of water will remove this. It discolors the skin and clothing, staining them yellow; this can not be removed by any treatment, though the garment may be dyed and the spot removed in that manner. Nitric acid is a strong oxidizing agent as it readily gives up its oxygen, thus:

$$2HNO_3 \rightarrow H_2O + 2NO_2 + O$$

On this account a piece of charcoal heated to redness and thrust into strong nitric acid will burn vigorously. For this reason, also, nitric acid behaves differently from most other acids toward metals. Instead of the hydrogen being liberated, the oxygen attacks the metal making an oxide of it, and then sometimes, the oxide is dissolved with the formation of a nitrate.

10. **Uses of Nitric Acid.**—One important use is as an oxidizing agent in the manufacture from aniline of the various coal tar dyes, an industry whose output has a value of millions annually. Another is in the manufacture of the various explosives used in numerous ways. Nitroglycerine is one of the more common. It is made by treating glycerine with fuming (brown) nitric acid, shown thus:

$$C_3H_5(HO)_3 + 3HNO_3 \rightarrow C_3H_5(NO_3)_3 + 3H_2O$$

The $C_3H_5(NO_3)_3$ is the nitroglycerine, more properly called glyceryl nitrate. It will be observed for every molecule of it obtained in the reaction there are three molecules of water produced at the same time. It becomes necessary to remove this water, otherwise the acid soon is so dilute that the reaction ceases. For this purpose fuming sulphuric acid is used which is a powerful dehydrating agent. The nitroglycerine then may be separated as a heavy oily liquid which does not mix with the diluted sulphuric acid. For the sake of convenience much of the nitroglycerine is made into dynamite; this is done by adding sawdust in varying amounts giving different grades of *giant powder* as it is called. Sometimes a siliceous earth, capable of absorbing large amounts of the oily nitrate, is used instead of sawdust. These explosives, as many others, are started by a *detonator,* like mercury fulminate, $Hg(CNO)_2$. A sharp blow will ignite this and the shock will start the nitroglycerine. The explosive property depends, as it does in nearly all cases, upon the fact that nitrates are as a rule exceedingly unstable bodies. There is enough or nearly enough oxygen contained in the nitroglycerine molecule itself for the combustion of the other elements present. The hydrogen is burned to water, the nitrogen goes off free and the carbon becomes carbon monoxide and dioxide. The quantity of gas produced is, therefore, enormous in proportion to the original volume, and the violence correspondingly great. Moreover, the heat of combustion greatly expands these gases and thus even greater effects follow.

Guncotton-Nitrocellulose.—As nitroglycerine is made by treating glycerine with fuming nitric acid and sulphuric so is this explosive, except cotton takes the place of the glycerine. The sulphuric acid serves the purpose of a dehydrating agent as before. Cellulose has the formula, $(C_6H_{10}O_5)_n$ and when treated with nitric acid we may introduce from three to six nitrate groups, the higher forms of the explosive having six groups. Its formula is $C_{12}H_{14}O_4(NO_3)_6$. It is produced from two groups of the cellulose formula thus:

$$2C_6H_{10}O_5 + 6HNO_3 \rightarrow C_{12}H_{14}O_4(NO_3)_6 + 6H_2O$$

Lighted in the open air it burns quietly, but detonated the combustion is almost instantaneous and the results terrific. In the lower form, the cellulose ternitrate, the explosive power is much less; it is frequently dissolved in ether and alcohol mixed and forms what is known as *collodion,* used in photography and as *new skin* in surgery. When dissolved in camphor it produces celluloid, while fiber silk is cotton nitrated as above, dissolved as for collodion, then in pasty form is forced through tiny openings like the spinneret of the silk worm. The explosive nitrate groups are then removed by further chemical treatment with calcium sulphide or some alkaline reagent. The appearance is not greatly different from real silk but the wearing qualities are considerably less, as the fiber is more brittle.

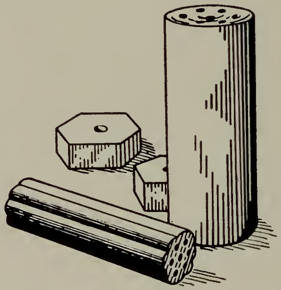


Fig. 26.—Some forms of smokeless powder.

Smokeless Powders and T. N. T.—When the hexanitrate of cellulose is treated with ether it forms a gelatinous mass which is pressed into molds of various shapes some of which are shown in Fig. 26 adjoined and sold under the name of smokeless powders. The products of combustion are the same as those mentioned in the case of nitroglycerine, all of which are colorless gases. Picric acid, otherwise known as trinitrophenol, with a formula of $C_6H_2(NO_2)_3OH$, is not only very explosive itself, but serves as the starting point for other high explosives. At the present time, October, 1918, we hear a great deal about T. N. T. a commercial term for trinitrotoluol. Its formula is

$C_6H_2(NO_2)_3CH_3$, and it is being used extensively in the high explosives in warfare. Toluol is a compound obtained from coal tar just as *phenol* or as it is often called, carbolic acid, is, and its explosiveness lies in the nitro groups as in all other cases considered.

Exercises for Review

1. Give two old names for ammonia. Why was it called thus?
2. What is the source of our commercial supply? How has it been allowed to go to waste?
3. Give the characteristics of ammonia? What other gas studied is also very soluble in water? How many barrels of ammonia gas will a quart of ice water dissolve?
4. What is produced when ammonia dissolves in water?
5. Name three uses of ammonia. Describe a refrigeration plant.
6. How may nitric acid occur in the air?
7. Give the usual way of manufacturing nitric acid. What newer process is being developed?
8. Name the oxides of nitrogen and give formulas.
9. Which of these is used medicinally? Why can it not take the place of ether or chloroform?
10. Why are the last three in the series of any interest to us?
11. Give the characteristics of nitric acid.
12. How does nitric acid behave differently toward metals from most other acids?
13. Name two industries with which nitric acid is closely associated.
14. What is the purpose of the two acids used in the manufacture of nitroglycerine?
15. What is dynamite? Giant powder? What advantage over nitroglycerine?
16. What is a detonator? Name the usual one.
17. How is guncotton made? What different varieties?
18. What is collodion? New skin? Celluloid? Fiber silk?
19. How are smokeless powders made? What advantage have they?
20. What is T. N. T.? Its use?
21. Wherein lies the explosive character of the various substances named?

CHAPTER XIII

VALENCE

Outline—

1. Meaning of Valence.
   Univalent Atoms and Groups.
2. Bivalent Atoms and Groups.
3. Trivalent and Quadrivalent Atoms and Groups.
4. Variation in Valence.
   (a) Apparent, Not Real.
   (b) Unsaturated Compounds.
   (c) Experimental Evidence.
5. Valence of Elements in Ternary Compounds.
6. Terms Used in Valence.

Exercises for Review.

1. **What Is Valence?**—The term, valence, is derived from a Latin word which means *power*: so in chemistry valence simply means power, the power which an atom or group of atoms acting together in a radical, has of combining with something taken as a standard. This standard of measurement is the hydrogen atom. So when an atom like chlorine has the power of combining with one atom of hydrogen and no more it is said to have a valence of one. This is shown in the compound, hydrogen chloride. Likewise, iodine has a valence of one, also bromine and fluorine, as each of them combines with one atom of hydrogen. This is seen in the compounds, HI, HBr, and HF. Positive elements, not being able to combine with hydrogen, must be measured by some electronegative, whose valence we have already measured by hydrogen. Such an ele-

ment is chlorine as it combines with practically all the positive elements. Thus, sodium has a valence of one, seen in the compound, NaCl: the same is true of potassium, seen in KCl. There is one positive radical with a valence of one, ammonium, seen in NH_4Cl; also several negative radicals. For example, HO, seen in NaHO; ClO_3, seen in $KClO_3$, NO_3, seen in KNO_3, etc.

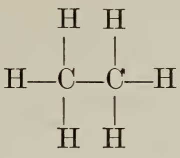
2. **Elements with a Valence of Two.**—The most common element with a valence of two is oxygen and as it combines with nearly all other elements it often serves as a means of measuring the combining power of the others. Water, H_2O, shows that oxygen has a valence of two. Sulphur forms the compound, hydrogen sulphide, H_2S, which indicates a valence of two for sulphur. Several of the common metals have a valence of two as shown by their oxides: thus, magnesium, MgO, copper, CuO, zinc, ZnO, etc. Two common radicals, SO_4, seen in sulphuric acid, H_2SO_4, and CO_3, seen in all carbonates, as carbonic acid, H_2CO_3, have a valence of two.

3. **Valence of Three and Four.**—Nitrogen and phosphorus both form hydrogen compounds, as NH_3, ammonia, and phosphine, PH_3. The radicals, PO_4 and BO_3, seen in phosphoric and boric acids respectively each has a valence of three, shown by their formulas, H_3PO_4, and H_3BO_3. For a valence of four carbon and silicon are the best examples, seen in the compounds carbon dioxide, CO_2, and silicon dioxide, SiO_2. We have met with no radical up to this time having a valence of four, but orthosilicic acid has the formula, H_4SiO_4, showing for SiO_4 a valence of four.

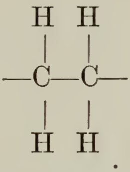
4. **Variation in Valence.**—In studying the binary compounds we noticed such as mercuric and mercurous

chloride and many others. Thus, $HgCl_2$ and Hg_2Cl_2, in the first of which mercury combines with two atoms of chlorine and in the second, one atom mercury combines with one of chlorine. Probably this atom always has the valence of two and is not variable; such compounds, then, as mercurous chloride, Hg_2Cl_2 are unsaturated and may be represented by the structural formula thus:

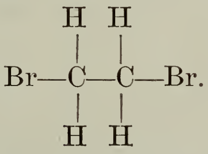
$\begin{array}{l}—Hg—Cl\\—Hg—Cl\end{array}$ and then if the molecule consists of the two unsaturated groups, as most believe, it is possible that the two unused bonds of the two mercury atoms ''swing around'' and hold loosely to each other. This is merely an assumption, however, as we know nothing about what this bond is. We do know, however, that the mercurous atom will readily take up another atom of chlorine and form the mercuric chloride. Again, iron forms two sets of compounds in the same way illustrated by the two chlorides, $FeCl_2$ and $FeCl_3$, ferrous and ferric chloride. As in the case of the mercury the ferrous compound is an unsaturated one and the real valence of the iron atom is three and not two. As proof of this the ferrous compounds are all very unstable and readily take some other electronegative element or group to complete the saturation. Another good example is carbon: we shall see that it forms two oxides, CO, and CO_2. We shall have good evidence also that carbon monoxide is an unsaturated compound in that it readily takes up more oxygen to form the dioxide. Many other cases of this kind are known in carbon compounds. Thus ethane, C_2H_6, is a saturated compound, each carbon atom having all four bonds in use, as shown by the following graphic formula:

C_2H_6 

$$H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-H$$

while ethylene, C_2H_4, with graphic formula, 

$$-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-$$

has two bonds with nothing attached. As experimental proof of this, if the first of these two compounds is passed through a solution of bromine, nothing happens, no matter how long the trial is continued: if the second is passed in the same way it is not long before the red color of the bromine solution has disappeared and in its place we have a colorless, oily liquid, which on analysis is found to contain two parts of bromine with the formula of $C_2H_4Br_2$ or shown graphically, thus: 

$$Br-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-Br.$$

This is only one case of a large number that may be given. It seems probable, therefore, in the light of such experiments that most of the so-called variation of valence is not variation at all, but a case of one of the compounds of the element in consideration not being saturated.

5. **Valence in Ternary Compounds.**—Often we wish to know the valence of a certain atom in a ternary compound. This is not difficult if it is remembered that the oxygen in the compound is the equivalent of both the other elements. Suppose it is desired to know the valence of chromium in potassium chromate, K_2CrO_4. The valence of oxygen is two; four atoms

would therefore have a valence of four times two, or eight. Two atoms of potassium would have a valence of two; subtracting the two of the potassium from the eight of the oxygen leaves six which is the valence of the chromium atom in the compound.

6. **Degrees of Valence Named How.**—Two sets of terms are used in designating the degree of valence of any element or group. Thus we may use the words *monad, diad, triad, tetrad, pentad;* or we may say *univalent, bivalent, trivalent, quadrivalent, quinquivalent.* Thus chlorine is a monad or a univalent element; carbon is a tetrad or a quadrivalent element.

Exercises for Review

1. What is meant by valence? What is our unit of measurement? Illustrate.

2. How can you determine the valence of an element if it will not combine with hydrogen? Illustrate.

3. Name four elements and four radicals with a valence of one.

4. Name four elements and two radicals with a valence of two.

5. What is the most common element with valence of two?

6. Name some elements with valence of three; some with four. Give proof.

7. What evidence can you give that valence of mercury atom is two when sometimes it appears to be one?

8. Give experimental evidence that ethane is a saturated compound; that ethylene is not saturated.

9. What do you understand by a saturated compound? An unsaturated one?

10. What is a graphic formula? Illustrate.

11. What is the valence of sulphur in sulphuric acid? Of manganese in potassium permanganate, $KMnO_4$? Of Cr in $K_2Cr_2O_7$?

CHAPTER XIV

CARBON AND A FEW COMPOUNDS

Outline—

1. Distribution of Carbon in Nature.
2. Forms of Carbon.
    - (a) Crystallized—
        - Diamond.
        - Graphite.
    - (b) Amorphous.
        - Natural.
            - Coals.
        - Artificial.
            - Charcoal.
            - Coke.
            - Lampblack.
            - Gas Carbon
3. The Diamond.
    - (a) Proof of Composition.
    - (b) Comparison with Allotrope, Graphite.
    - (c) Origin of Diamonds.
    - (d) Artificial.
    - (e) Uses.
4. Graphite.
    - (a) Characteristics.
    - (b) Uses
5. Charcoal.
    - (a) Preparation.
    - (b) Uses.
6. Coke.
7. Coal Gas.
    - (a) Preparation.
    - (b) By-products.
8. Gas Carbon.

9. Natural Coals.
    - (a) Formation.
    - (b) Varieties.
    - (c) Natural Gas.
    - (d) Petroleum.

10. Compounds of Carbon.
    - (a) Carbon Monoxide.
        - Various Sources of.
        - Danger of.
    - (b) Carbon Dioxide.
        - Value of.
        - Practical Uses.
    - (c) Carbon Tetrachloride.
        - Practical Uses.
    - (d) Carbides.
        - Calcium Carbide.
        - Silicon Carbide.
        - Iron Carbide.

Exercises for Review.

1. **Distribution in Nature.**—Carbon is an interesting element because of the variety of forms in which it appears. In marble, limestone, corals, and similar forms it exists as a carbonate, crystallized or not, and often beautifully colored. It is in the air in the form of carbon dioxide and is also familiar in many ways in the free state more or less pure and very widely distributed.

2. **Allotropic Forms.**—The purest form of carbon is the diamond: allotropic of this is graphite, and the artificial forms of charcoal, coke, gas carbon and lampblack. The various coals known to all are not pure carbon, but contain in addition some hydrogen, nitrogen, and smaller quantities of some other substances.

3. **The Diamond.**—Looking at a diamond and a piece of graphite, one could hardly believe that they are the same substance. It is not difficult, however, to prove

that they are both carbon, for each, burned in an atmosphere of oxygen, produces only one substance, carbon dioxide. If a diamond is heated strongly in the absence of air it swells up and becomes dark, resembling graphite somewhat; but if heated to 700° C. in a tube filled with oxygen it disappears, and leaves little or no residue, while in place of the oxygen we now have carbon dioxide. See Fig. 27 to show method. The diamond is put into the bulb of the combustion tube, a current of oxygen is then passed through to remove the air, the ends are closed loosely and the heat applied with results as stated.

Comparison of Diamond with an Allotropic Form.—The diamond is the hardest mineral known, but graphite is one of the very softest; the diamond is colorless, graphite is black; diamond is a poor conductor of electricity, graphite a good conductor; diamond has a density 3.5 times as heavy as water, graphite 2.3 times, and charcoal, another allotrope, has a density less than 2; diamond crystallizes in octahedrons and graphite in hexagonal plates. So it seems, if they were entirely different substances, they could hardly be more different than they are.

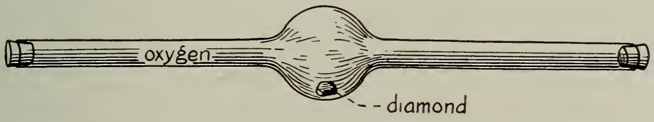


Fig. 27.—Burning of a diamond.

Origin of Diamonds.—Nothing positive can be asserted regarding the origin of diamonds, but they are believed to have been produced under great pressure, and sufficient heat to render the carbon more or less nearly molten. We have some evidences of this in the artificial diamonds made by the French chemist Moissan some few years ago. The carbon he used was obtained by charring loaf sugar; this was mixed with iron turnings and placed in an electric furnace. Molten iron has the power of dissolving carbon, hence portions of the carbon thus entered into solution. Moissan then plunged the whole mass into ice water, whereupon the outer portions of the molten iron solidified and thus put great pressure upon the interior portions of the mass. In this way the dissolved carbon crystallized. When the mass was cool it was broken up, and the iron dissolved away by nitric acid. This left the diamonds in his beaker. Unfortunately they were all very small and more or less dark colored, but in other respects they had the properties of natural diamonds. See Fig. 28 which shows the form of electric furnace used by Moissan.

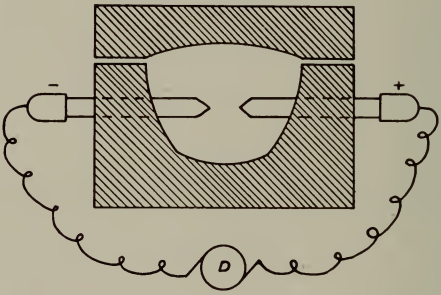


Fig. 28.—Moissan's electric furnace.

Uses of Diamonds.—In ancient times diamonds were prized for their beauty but as no way was known of cutting them they did not come into general use as ornaments until it was discovered they might be ground in their own dust. The largest diamond ever found weighed 3032 carats before cut; this was known as the Cullinan. Diamonds of such size are of little use, however, unless cut into smaller ones. Such as are imperfect and unsuited as ornaments, are made into bearings for delicate instruments such as fine watches, assay balances, and the like. They are also mounted for cutting glass, for drilling through difficult rock formations, sawing stones, and as dust for cutting and polishing other precious stones.

4. **Graphite.**—Nearest related of the allotropic forms of the diamond is probably graphite. It is not abundantly found in nature and to meet the present demand considerable is manufactured in electric furnaces. It has a soft, greasy feel, is very friable, not affected by the air or high temperatures, a good conductor of electricity. On account of these properties it has many uses. The most familiar to the general public is in the form of the so-called lead pencils, named thus when the character of graphite was misunderstood. The various grades of pencils, ranging from soft to very hard are obtained by thoroughly mixing varying amounts of fine clay with the powdered graphite, making it into a thick paste and forcing it through tiny apertures in the shape of the familiar "leads." As it is not affected by the air it is used to coat shot, the grains of black and giant powder and as a polish for stoves. Because of its resistance to heat it is used in crucibles, and on account of conductivity, in various ways in electrical applications. For example, in making electrotypes for printing books and magazines, the wax impression is coated with powdered graphite before it is possible to obtain a deposition of the copper as the basis of the plate.

5. **Charcoal.**—Charcoal is an artificial allotrope of the diamond. Formerly it was made by covering wood with earth and sod and by burning some considerable

portions of it the remainder was left as charcoal. It was an exceedingly wasteful method and is no longer followed. Now, the wood is placed in iron retorts and heated from beneath by coal which is a much cheaper fuel. Besides saving the wood formerly consumed for heat, such by-products as acetic acid, wood alcohol and acetone as well as several others which are now saved, more than pay the cost of manufacture. Besides wood, vast quantities of bone are made into charcoal; and just at the present time, considerable amounts of cocoanut shells and those of other nuts as well as the pits of the peach and other fruits.

Uses of Charcoal.—The uses of wood charcoal are familiar to most. Besides as a fuel in braziers and other small open fires, it is used in filters for cisterns in country homes. In such cases it should be removed at least once a year and heated red hot to destroy impurities. Bone charcoal, or bone-black, as it is often called, is used mainly for clarifying sugar and other organic compounds. It is considerably more porous than wood charcoal hence has greater absorptive powers. Ivory black, a well known black paint, is made from tusks and similar animal products, such as are not suited for manufacture into more valuable articles. Charcoal made from nutshells has especially strong absorptive powers and has been used in research laboratories in isolating the rare gases of the atmosphere for some years: but it remained for the World War to create a great demand for such charcoal. During 1918 carloads of nut shells were made into charcoal for use in gas masks.

6. **Coke.**—As charcoal is made from wood, so coke is made from certain varieties of coal. It is placed in

retorts or often in "bee-hive" ovens and heated strongly until the volatile products have passed off. The residue is a dark, grayish product, used largely in foundries and smelters for fuel and reduction purposes. It gives a much more intense heat than the coal from which it is made would give and is desirable for this reason.

7. **Coal Gas.**—When soft coal is heated in retorts as indicated in the preceding section, several combustible gases are expelled: when these have been purified, they constitute the coal gas used as cooking fuel and for lighting in most cities. Besides the combustible gases driven off two other volatile products are obtained. The first of these is coal tar, and the second is ammonia. The second has already been mentioned in another chapter. Coal tar is a very complicated mixture of numerous compounds, black because of the presence of small amounts of free carbon particles. In some ways it is the most wonderful mixture known to the chemist. From it are obtained the compounds from which are prepared nearly all the beautiful dyes now used in commerce; most photographic developers and many *indicators,* of inestimable value to the chemist, have their source here; many headache and other medicines are made from coal tar products; phenol, carbolic acid, and its derivative picric acid, together with explosives made from it; toluol and trinitrotoluol also originate here. And with this the story is probably not half told.

8. **Gas Carbon.**—In the manufacture of coke in retorts a hard, fine-grained deposit slowly forms upon the interior of the retorts. At intervals this is scraped off, ground up and molded into various shapes for use.

It is an excellent conductor of electricity and one familiar use of it is in the carbon sticks used in arc lights for street and other lighting. It is also used in dry cells as one of the electrodes.

9. **Natural Coals.**—At an age of the world when there was probably much more carbonic acid gas in the atmosphere than at present, great forests were produced, surpassing in all probability anything known at the present time even in the tropics. These forests in some unknown way, possibly from great tidal waves, were buried at depths which prevented decay and at the same time brought them under the influence of much heat and pressure. The result was that a greater or less amount of the volatile matter contained in the wood was expelled, and the wood was changed into what we now call coal. In cases where the heat was slight and only minimum changes took place lignite coal remains, often brown in color, very soft, frequently showing even the woody structure and knots of the trees themselves. With more heat and pressure, greater changes took place, forming harder grades of bituminous coal, but still the product contains much volatile matter. It is from this variety of coal that coke is made. At still higher temperatures, more of the bitumen was expelled with the formation of semi-anthracite coal, and then finally, anthracite, having no volatile residue at all. Carried still further in extreme cases the anthracite coal became graphite and lastly, in still rarer cases, the diamond.

The Volatile Portions.—A portion of the volatile matter driven off at various stages in the transformation of wood into coal was in the form of gas; much of this undoubtedly escaped into the air and was lost:

some of it was caught below impervious layers of rock and there remained until drilled into, when it escaped, sometimes with enormous pressure and this is our natural gas. Other portions on cooling were liquids and form at least a considerable part of our petroleum deposits. These natural oils are of two classes; one, a *paraffin* bearing oil and the other an *asphalt* bearing oil. The former are more desirable, as a much greater quantity of refined products may be obtained from them. In distilling such oils, the portion coming off below 150° C. is classed as gasoline. This may be fractionated, however, into several portions, giving us petroleum ether, rhigolene, benzine, naphtha, and gasoline. Between 150° and 300° kerosene is obtained; and above this in successive fractions, heavy burning oils, paraffin oil, lubricating oils, vaseline, paraffin, etc. Originally, the percentage of gasoline, the most desirable fraction, in petroleum is not large; but by a process of "cracking" different with the different refining companies, the heavier portions are broken up so as to increase greatly the amount of gasoline obtained. The asphalt oils after the lighter fractions are removed are used in road making, oiling boulevards, sprinkling railway tracks to prevent dust, as fuel in engines, and various other ways. By many scientists they are supposed to be of animal origin while the paraffin oils are believed to be of vegetable.

10. **Compounds of Carbons.**—*Carbon Monoxide, CO.*—Carbon forms two oxides, with one of which we are more or less familiar. The other is carbon monoxide. It is always formed when carbon is burned in a supply of air not sufficient to give complete combustion. It is also formed when carbon dioxide passes over or

through red-hot carbon, in which case the carbon takes away a part of the oxygen from the dioxide. There are several ways in which carbon monoxide finds its way into our homes. Most furnaces are made of cast iron: at night when banking the fire before retiring, a considerable amount of cold fuel is thrown in, the draughts are closed and the result is the formation of quantities of the monoxide. Fig. 29 will make this clear. In the lower part of the fire box as the air comes in from the ash pit carbon dioxide will be formed; as this flows up through the mass of red-hot coal half the oxygen is removed, thus:

$$CO_2 + C \rightarrow 2CO$$

Now this passes on up through the fire and under ordinary circumstances meeting air above the fire which comes in through the draft in the door would burn and produce again the dioxide. This is easily seen in an anthracite fire in a furnace or base-burner, in the blue lambent flame, playing over the surface. But when a layer of cold fuel is present the monoxide is cooled below its kindling point and does not burn till the new layer has become hot; in the meantime it is being occluded by the red-hot cast iron wall of the fire box and transmitted promptly through it to the air chamber on the other side, from which it is carried up into the living rooms above. The odor of the gas can be detected in such cases very soon after banking the fire. The same thing happens in base-burners when much coal is shaken down into the fire box. Again, tobacco smoke contains a considerable amount of carbon monoxide. It is produced as just explained. At first carbon dioxide is formed, then this being drawn back through the layer of red-hot tobacco is reduced to the monoxide and expelled as such into the room. A gas mantle, which shows any sign of becoming black from deposit of carbon is always producing the monoxide because it is not obtaining a plentiful supply of air. Gas heaters when burning with a yellow flame instead of blue are offending in the same way and for the same reason. Likewise, cook-stoves whenever the flame is yellow, are not receiving sufficient air to completely burn the gas and are producing more or less carbon monoxide. Thus it is seen this compound may find its way into our living rooms in various ways.

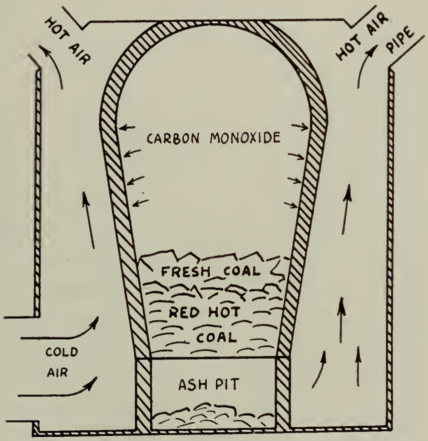


Fig. 29.—Formation of carbon monoxide in a furnace.

Danger of Carbon Monoxide.—Carbon monoxide is a colorless gas, slightly lighter than air, burns with a pale blue flame, has a peculiar faint odor, more or less stifling, and very poisonous. It attacks the hemoglobin and renders the blood incapable of carrying oxygen, hence asphyxiation and death soon follow its continued respiration. Numerous cases of suicide are on record where death was secured by covering an open charcoal fire with considerable fresh fuel and retiring in the same room. Knowing the poisonous character of this gas it is important to guard against breathing it. Sleeping rooms, warmed by furnace, should have the registers closed at night and outside windows opened. Gas jets used for lighting or heating should have air so regulated as to secure complete combustion and prevent the formation of the poisonous oxide.

Carbon Dioxide, CO_2.—As elsewhere stated carbon dioxide constitutes from three to four hundredths of one per cent of the air. Its use to plant life has also been suggested. It is a colorless gas, not combustible, will not permit of the combustion of other substances with rare exceptions, is slightly soluble in water, forming the theoretical carbonic acid; is about once and a half as heavy as air, and not poisonous.

Uses of Carbon Dioxide.—One of the most familiar uses of this gas is in the making of soda water; under great pressure the gas is admitted to cold water from gas cylinders and is absorbed to a considerable extent. As soon, however, as the pressure is removed which happens when the soda water is drawn from the faucet, the gas begins to escape producing the familiar effervescence. It is the dissolved carbon dioxide which gives the familiar, biting taste of such water; cider, a few days old, effervesces because of the presence of carbon dioxide, and owes its sharp taste partly to the same cause.

The common fire extinguisher, seen in the corridors of many public buildings, owes its efficiency largely to the carbon dioxide generated when put into use. Fig. 30 will show how it works. The brass container is filled with water nearly to the top. A pint bottle, with a porcelain or lead stopper fitting so loosely that it will fall out if inverted, is nearly filled with sulphuric acid; in the water is a pound or more of common cooking soda. When desired to use, the extinguisher is turned upside down; the acid is emptied into the soda solution and a rapid evolution of carbon dioxide takes place, as shown by the equation,

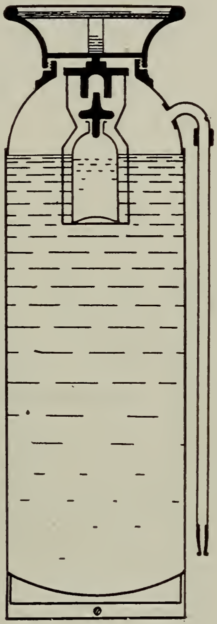


Fig. 30.—Babcock fire extinguisher.

$$NaHCO_3 + H_2SO_4 \rightarrow CO_2 + NaHSO_4 + H_2O$$

The pressure obtained at the same time throws a vigorous stream of water and gas on the fire.

Carbon Tetrachloride, CCl_4.—This is not a compound well known to the public, but it has some uses which render it valuable. It is a fine solvent for oil, grease and like substances, is not inflammable, like gasoline, and not very expensive. Hence it may safely be employed in the household instead of gasoline for removing spots from clothing. "Pyrene," a largely advertised fire extinguisher consists largely of carbon tetrachloride. When thrown upon a fire, it is rapidly vaporized, and the vapors being heavy and not combustible, smother the fire. "Carbona," another commercial article advertised for cleaning garments is largely this same compound with some benzine present but not enough to be inflammable in the presence of the heavier liquid.

Carbides.—There are several binary compounds of carbon now assuming considerable commercial importance. One of these is calcium carbide, CaC_2, used in the manufacture of acetylene, which will be mentioned elsewhere. Calcium carbide is made in electric furnaces at such places as Niagara Falls, where water power may be had cheaply. The following equation shows the chemical change:

$$CaO + 3C \rightarrow CaC_2 + CO$$

Carborundum, SiC, is made in a similar way by fusing together sand, SiO_2, and coke. The equation follows:

$$SiO_2 + 3C \rightarrow SiC + 2CO$$

It is used very extensively as an abrasive. It is crushed to a powder, mixed with some cementing material and by hydraulic pressure, made into whetstones, wheels for grinding and polishing and for all purposes where emery is used. It is much harder than emery, hence cuts faster. It is the hardest of all substances except the diamond and by some it is claimed even to surpass the diamond.

A third, iron carbide, is not an article of commerce, but its great value demands a brief notice. When steel is made a small amount of the carbon present in the iron combines with iron and forms the carbide. It is this which gives the hardness to steel and renders possible its being tempered and made into cutting tools.

Exercises for Review

1. What are some of the ways in which carbon appears in compounds in nature?
2. Name two allotropic forms of pure, crystallized carbon.
3. Give proof that the diamond is pure carbon.
4. Compare the diamond with graphite.
5. Describe Moissan's method of making diamonds. What value has this experiment?
6. Give several uses of diamonds in a practical way. Upon what property do all these uses depend?
7. What practical uses has graphite?
8. How is charcoal made now? What by-products are obtained?
9. Name two varieties of charcoal: Give special uses of each.
10. How is coke made? What is main use?
11. How is coal gas made? Name four by-products obtained.
12. Name the various products obtained from coal tar.
13. What is gas carbon? Its two main uses?
14. How were coals formed? Give three classes of coals. How different?
15. In the formation of coals what two other products formed?
16. What two kinds of petroleum? Which is the more valuable? Why?
17. What is meant by ''cracking'' an oil?
18. Name the various products obtained from petroleum.
19. What are some of the ways carbon monoxide gets into our homes?

20. What danger accompanies the presence of carbon monoxide?

21. Give characteristics of carbon dioxide. Is it poisonous?

22. What practical uses has carbon dioxide? Value to plants?

23. Describe the Babcock fire extinguisher.

24. Give some valuable uses for carbon tetrachloride. What is pyrene?

25. What is carbona? Uses?

26. Name three carbides. How are two of them made?

27. Give uses of the three carbides named.

CHAPTER XV

SOME EVERYDAY CARBON COMPOUNDS

Outline—

1. Hydrocarbons, What?
    - (a) The Paraffins.
    - (b) Methane.
    - (c) The Gasoline Series.
    - (d) Kerosene.
2. Hydrocarbon Derivatives.
    - (a) Chloroform, Iodoform.
    - (b) The Alcohols.
    - (c) Organic Acids.
    - (d) The Aldehydes.
    - (e) Ethers.
    - (f) Ethereal Salts.
    - (g) Glycerine.
    - (h) Edible Fats.
3. Oleomargarine.
4. Soaps.
    - (a) Method of Manufacture.
    - (b) By-product Formed.
    - (c) Chemistry of Cleansing.
5. The Olefines.
6. Vegetable Oils and Hydrogenation.
7. The Acetylenes.
8. Carbohydrates.
    - (a) Composition.
    - (b) Glucose.
    - (c) Sucrose-Cane and Beet Sugar.
    - (d) Starch.

Exercises for Review.

1. **Hydrocarbons.**—A hydrocarbon is a compound of carbon and hydrogen, as the name indicates. Somewhere near a hundred thousand hydrocarbons, including compounds derived from them, have been prepared and studied. A very few of these are of importance to us in everyday life. In a preceding chapter mention was made of paraffin—base petroleums and of the large number of compounds obtainable from such oils. Really all these belong to a single series called *the paraffins* with a very simple relation existing among them. The first six of the series are given below although over sixty are known:

Methane,	CH_4
Ethane,	C_2H_6
Propane,	C_3H_8
Butane,	C_4H_{10}
Pentane,	C_5H_{12}
Hexane,	C_6H_{14}

The others of the series receive their names as do the fifth and sixth from the Greek numerals corresponding to the number of carbon atoms present. Thus, in hexane it will be observed there are six carbon atoms.

Methane or Marsh Gas, CH_4.—This gas is being produced at the bottom of ponds and creeks, wherever organic matter, as sticks and leaves, is undergoing decomposition. It was largely this produced when coal was forming from the buried forests; and the supplies of natural gas furnished our cities is about 95 per cent marsh gas. It is colorless, almost odorless, a little more than half as heavy as air, very inflammable, hence explosive when mixed with air. It is this gas, known to coal miners under the name of "fire damp" which causes the explosions in the mines. When the explosion takes place as the supply of air is limited, the resulting product from the carbon is carbon monoxide, known to the miners as ‘‘after damp’’ or ‘‘black damp;’’ it is this poisonous gas that usually causes most of the deaths in such cases. Incidentally it might be mentioned that carbon dioxide by miners is often called ‘‘choke damp,’’ showing that they recognize the difference between these several gases.

The Gasoline Series.—We have seen that gasoline is a mixture of several oils: in reality, it is composed mainly of the sixth, seventh, and eighth in this series, and the different oils mentioned are simply different combinations of these three. Kerosene consists of the next eight in the series. It will be seen that each one is CH_2 greater than the preceding one: since this close relation exists it does not seem strange that the process of ‘‘cracking’’ previously mentioned is possible in obtaining an increased amount of gasoline from any sample of petroleum. Summing up, then, it will be noticed that in this series, all of which are known as paraffins, the first five are gases, the next considerable number are liquids of constantly increasing boiling point, and those higher up are the solid paraffin familiar to all.

2. **Hydrocarbon Derivatives.**—A hydrocarbon derivative is a compound formed by substituting something for one or more of the hydrogen atoms in the compound. From methane, CH_4, are derived two very familiar compounds, of interest and value, already mentioned elsewhere; chloroform, $CHCl_3$, and iodoform, CHI_3. Their use is well known and mentioned under chlorine.

Other Derivatives.—The alcohols may also be regarded as derivatives of the paraffins, in which hydroxyl, HO, has been substituted for hydrogen. Thus:

CH_4 would give CH_3OH, one hydrogen being replaced; C_2H_6 would give C_2H_5OH, and so on for the series.

The first of these is methyl, or wood alcohol, and the second is ethyl, or grain alcohol. The first is obtained from the distillation of wood in making charcoal and the second by the fermentation of grains. *Denatured* alcohol is ethyl alcohol which contains usually about 10 per cent of some other substance which renders it undrinkable and unfit for use in any medicine or food product. Sometimes this adulterant is wood alcohol, sometimes benzine; the government allows at present several modifications so as to adapt the use of a cheap solvent to a very large number of practical applications.

Preparation of Alcohol.—As already stated ordinary alcohol is made from grain. Before fermentation with the production of alcohol can take place, the starch in the grain must be changed. This is brought about by the action of an enzyme, diastase. The grain is dampened and kept warm until it begins to grow; during this period the starch is converted by the enzyme, at least partly, into a form of sugar; at the proper stage, the grain is dried, which stops the process. It is then crushed or ground, yeast is added and the process of fermentation goes on with the formation of the alcohol. The steps will be shown by the following equations:

$$(C_6H_{10}O_5)_n + nH_2O \rightarrow nC_6H_{12}O_6$$

The water is added to the starch through the action of the enzyme, diastase, already mentioned.

$$C_6H_{12}O_6 \rightarrow 2CO_2 + 2C_2H_5OH$$

To separate the alcohol from the water it must be distilled. This has to be done several times, for while the boiling point of alcohol is about 78° C. and that of water 100° still considerable water comes over with the alcohol. That usually put upon the market is about 95 or 96 per cent pure. To obtain absolute alcohol this commercial article is treated with lime or anhydrous copper sulphate and allowed to stand 24 to 48 hours until the water has been absorbed and then separated and distilled.

Organic Acids.—These are derived from the alcohols by oxidation. Thus,

Methyl Alcohol, $CH_3OH + O_2 \rightarrow HCOOH + H_2O$
Ethyl Alcohol, $C_2H_5OH + O_2 \rightarrow CH_3COOH + H_2O$

It will be noticed that two of the hydrogen atoms in the alcohol have been oxidized to form water and also an atom of oxygen added to the alcohol molecule. Every organic acid contains the group COOH and their formulas are written so that we may recognize an acid at once by the formula. The first of those just above is known as formic acid, from the Latin name, *forma*, meaning an ant; it was so named because it is secreted by certain species of ants and its odor may be readily detected upon disturbing an ant hill. It is also secreted by wasps and bees and similar stinging insects, and it is this which causes the pain when injected into the tiny wound produced by the stinger. Being acid in character, therefore, the natural antidote is an alkali, and common soda being always accessible, serves the purpose well.

Acetic Acid.—This acid in dilute form is familiar to every one as vinegar, which runs from 3 to 5 per cent acid. Formerly it was made largely from cider: the apple juice contains grape sugar, which undergoes, first a *vinous,* that is, alcoholic fermentation, as has been seen in the second step of the preparation of grain alcohol: then, another germ also found in the air, causes a second change whereby the alcohol is oxidized to vinegar. Pure acetic acid is a colorless liquid which solidifies at 16.7° C. and boils at 119°. Such acid is known as *glacial* acetic. It has a sharp, penetrating odor, more or less irritating.

The present demand for acetic acid is so great that only a small percentage comes from the fermentation of cider. The distillation of wood in making charcoal furnishes a considerable amount, but probably the greater proportion is made from glucose which is largely obtained from cornstarch. By means of a dilute acid the starch is converted into glucose and the acid is then carefully neutralized and removed. The glucose then is slowly passed through tanks, containing shavings which have been inoculated with the "mother of vinegar," *Mycoderma aceti,* the germ which produces the fermentation, and the oxidation rapidly takes place. It is made cheaply this way, and if vinegar is a wholesome article of diet at all, is far preferable to that made from cider. The latter frequently contains besides considerable portions of decomposed organic matter, numerous vinegar eels, tiny white worms which may be seen on close inspection. Vinegar made from glucose may be colorless or of the usual brown color due to small portions of carmel added for the purpose.

Aldehydes.—There is only one, formaldehyde, in which we are interested. But there are a number of them, all derived at least theoretically from the alcohols by oxidation carried only half as far as in the case of the acids. That is, when the oxidation takes place, two hydrogen atoms are removed from the alcohol molecule with the formation of water, but no oxygen is added, as was the case with the acids. Thus:

$2CH_3OH + 2O_2 \rightarrow 2HCOOH + 2H_2O$ Formic Acid produced

$2CH_3OH + O_2 \rightarrow 2HCOH + 2H_2O$ Formic Aldehyde produced

$2C_2H_5OH + 2O_2 \rightarrow 2CH_3COOH + 2H_2O$ Acetic Acid formed

$2C_2H_5OH + O_2 \rightarrow 2CH_3COH + 2H_2O$ Acetic Aldehyde formed

Formic Aldehyde.—Formic aldehyde is a gas at ordinary temperatures but may be liquefied at a temperature of –21° C. Formalin, the commercial article, is a 40 per cent solution of formaldehyde in water. The gas has a peculiar, irritating odor, affecting especially the eyes and nostrils. It is strongly germicidal and two or three drops in a glass of water serve excellently as a mouth or throat wash. It should not be swallowed. It is used extensively as a preservative for zoologic and anatomic specimens, being much better than alcohol. It hardens the tissues and puts them into much better condition for making microscopic examinations if such are desired. It is also largely used as a disinfectant in case of epidemics of contagious diseases, in that it is not expensive and is easy of application. This is often done by pouring on lime. The heat generated drives the gas out quickly.

Ethers.—There is a series of ethers corresponding to the alcohols. Ethers are really oxides of organic radicals or hydrocarbon groups. Thus:

$$2CH_3OH \rightarrow (CH_3)_2O + H_2O \quad \text{Methyl Ether}$$
$$2C_2H_5OH \rightarrow (C_2H_5)_2O + H_2O \quad \text{Ethyl Ether}$$

It is only the second one in the series in which we are interested. It will be observed that they obtain their names from the alcohols from which they are derived. Ethyl ether, or as it is often called, ''sulphuric ether,'' because sulphuric acid is used in the manufacture of it, is a colorless liquid, with a rather pleasant, sweet odor; it is very volatile, having a boiling point of 34.9° C. which is below the temperature of the human body. It is an excellent solvent for iodine, and various organic substances, such as oils, and fats. It is commonly used as an anesthetic, but on account of its inflammability which is even greater than that of gasoline, it is dangerous in the presence of any open flame. In common practice probably more often chloroform and ether are used mixed.

Esters or Ethereal Salts.—Just as the mineral acids and bases may combine to form salts, which we have already studied, so the organic or carbon acids and bases may. It must be noted that the organic bases or hydroxides we call alcohols. If acetic acid and ethyl alcohol are put together and warmed gently a very agreeable fruity odor is obtained due to the ethyl acetate formed. This acetate is an ethereal salt and the action is shown in the equation

$$C_2H_5OH + CH_3COOH \rightarrow C_2H_5CH_3COO + H_2O$$

It will be noticed that water is one of the products formed here as it was with the mineral acids. The word, *ester,* is derived from the two words, ethereal salts, and has no special meaning in itself. The esters are of interest from the fact that the artificial extracts of apple, pear, banana, etc., found at the groceries and in the sirups of the soda fountains belong to this class of compounds. Thus:

Ethyl Butyrate,	Artificial	Pineapple
Amyl Valerate,	"	Apple
Isoamyl Acetate,	"	Pear

The glyceryl esters will be mentioned later.

Glycerine, $C_3H_5(OH)_3$.—It will be observed from the formula for glycerine that it is an alcohol containing three hydroxyl groups. It is a by-product of the soap factories; formerly it was left in the soap, but on account of its great commercial value it is now separated except in few cases where a special soap is desired. It is a thick, sirupy liquid, with a sweet taste, named for this reason from the Greek word for *sweet.* It is very soluble in water and is hygroscopic. On this account when the price admits, it is sometimes added by bakers to cakes to keep them moist. The chief use for glycerine is for the manufacture of explosives as already described.

Glyceryl Salts.—As glycerine, or more properly called, *glycerol,* is an alcohol or organic base, it forms salts, or esters. Many of these are of extreme value, as they are the ordinary oils and fats used for food. Thus, butter, olive oil, cottonseed oil, beef fat, lard, etc., are all glyceryl salts.

Butyrin—$C_3H_5(C_3H_7COO)_3$—Glyceryl Butyrate
Palmitin—$C_3H_5(C_{15}H_{31}COO)_3$—Glyceryl Palmitate
Stearin—$C_3H_5(C_{17}H_{35}COO)_3$—Glyceryl Stearate
Olein—$C_3H_5(C_{17}H_{33}COO)_3$—Glyceryl Oleate

The ordinary edible fats such as those of beef, pork and mutton, are mixtures of the last three named above. The greater the proportion of stearin present, the higher the melting point, while an excess of olein gives a fat easier to melt, hence softer in warm weather. Common lard contains about 60 per cent olein and 40 per cent of the other two. Butter is a mixture of all four of the above, containing when free from water, about 8 per cent of butyrin. Olive oil, a liquid at ordinary temperatures, is about three fourths olein. ''Mazola'' an oil made from corn as a by-product in the manufacture of glucose, and cottonseed oil are not specially different in composition.

3. **Oleomargarine.**—At the present time there is a very large variety of these artificial butters being offered on the market. Most of them are mixed animal and vegetable fats and oils, though several entirely vegetable are now to be had. All the better grades are probably good, are as wholesome, and as nourishing as real butter and may well be used instead. It is largely sentiment merely that prevents their use, and no good reason. Three formulas for manufacture of three different grades as used by one of the large packing houses are given below:

Formula No. 1.

Neutral Lard	75	pounds
Peanut Oil	75	‘‘
Cottonseed Oil	175	‘‘
Oleo Oil	675	‘‘
Skim Milk	60	gallons

These are put together and churned, the milk being used to give more of the flavor of real butter. There are then added:

Creamery Butter	150	pounds
Salt	125	‘‘
Total weight	1275	‘‘

This does not include the water which is taken up in the churning and later process of working the butterine. The water may run as high as 12 to 14 per cent.

Formula No. 2.

Neutral Lard	50	pounds
Peanut Oil	225	‘‘
Cocoanut Oil	50	‘‘
Oleo Oil	675	‘‘
Skim Milk	60	gallons
Salt	125	pounds
Weight	1125	pounds

The process is the same as in the preceding.

Formula No. 3.

Neutral Lard	50	pounds
Peanut Oil	100	‘‘
Cottonseed Oil	125	‘‘
Oleo Oil,	725	‘‘
Butter	400	‘‘
Skim Milk	60	gallons
Salt	125	pounds
Weight	1575	‘‘

Method pursued is same as above.

Some of the nut oleos now being introduced contain more of the glyceryl butyrate than the animal oleos and more nearly resemble real butter in taste on that account. Their chief objection seems to be in the lower melting point, which makes them more difficult of handling in hot weather. But they are a wholesome and nutritious article of food. It may be of interest to know how greatly the use of vegetable fats has been increasing in late years. Government reports show that in 1914 cocoanut oil, which is used mainly for the manufacture of nut oleos, was imported to the amount of seventy-four million pounds, while in the present year, 1918, it has amounted to 259 million pounds. Peanut oil increased in amount from one million gallons in 1914 to over eight million, and peanuts from 18 million pounds to 76 million. Soy bean oil in 1914 was imported to the amount of 16 million pounds, while this year it was 337 million.

4. **Soap Making—Saponification.**—The art of soap making has been known for centuries but for many years soap was used merely as a pharmaceutic preparation and not as a detergent, hence made on a very small scale. Now it is one of the great industries of the world. It is prepared by the union of caustic soda or potash with some fat or oil. As organic compounds react slowly, the mixture must be kept at the boiling point for several days during which time the following reaction takes place:

$$3NaHO + C_3H_5(C_{17}H_{35}COO)_3 \rightarrow 3NaC_{17}H_{35}COO + C_3H_5(HO)_3$$

The reaction has shown only stearin but of course fats being mixtures of several esters the soap formed would likewise be a mixture. It will be noticed that glycerol is the by-product formed. If potassium hydroxide is used instead of sodium hydroxide the product is a soft soap, which remains as a soft pasty mass and the glycerine is not separated out. Some years ago farmers made about all the soap they used, especially for laundry purposes, from the wood ashes obtained in the winter from their stoves. Sometimes they made this soft soap which wood ashes give into hard soap by adding salt to the finished product. The hard soap then separates out, rises to the top and when cold may be lifted off and cut into cakes.

$$KC_{17}H_{35}COO + NaCl \rightarrow NaC_{17}H_{35}COO + KCl$$

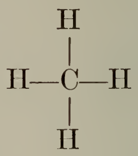
How Soap Cleanses.—There seems considerable doubt as to the action of soap in removing dirt from an object. As a rule foreign matter which we call ''dirt'' is held to the body or to articles of clothing largely through oily matter. If this can be removed the dirt is carried away mechanically by the water or whatever the liquid may be. When gasoline or carbon tetrachloride is used there is no question about the action. The grease is simply dissolved; then there is nothing to hold the foreign matter and it is removed. It is believed now that when soap is used an emulsion is formed by it and the oil and that then the water removes the dirt.

5. **The Olefines.**—With one exception the compounds we have just been studying may be regarded as derivatives of the paraffins. There is another class of hydrocarbons known as the olefines, the lowest in the series of which is ethylene, with a formula of C_2H_4. The first six of them are:

C_2H_4	Ethylene
C_3H_6	Propylene
C_4H_8	Butylene
C_5H_{10}	Pentylene or Amylene
C_6H_{12}	Hexylene

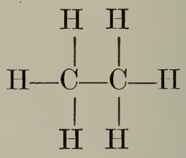
These are all what are called unsaturated compounds as explained in the chapter on Valence. If we express this by a graphic formula which is an attempt to show exactly how the various atoms are linked together, it is thus:

Methane, CH_4



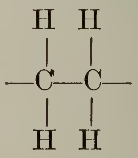
$$\begin{array}{ccccc} & & H & & \\ & & | & & \\ H & — & C & — & H \\ & & | & & \\ & & H & & \end{array}$$

Ethane, C_2H_6



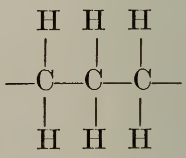
$$\begin{array}{ccccccc} & & H & & H & & \\ & & | & & | & & \\ H & — & C & — & C & — & H \\ & & | & & | & & \\ & & H & & H & & \end{array}$$

Ethylene, C_2H_4



$$\begin{array}{ccccccc} & & H & & H & & \\ & & | & & | & & \\ — & & C & — & C & & — \\ & & | & & | & & \\ & & H & & H & & \end{array}$$

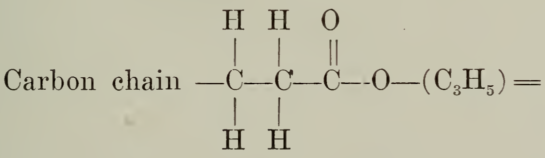
Propylene, C_3H_6



$$\begin{array}{ccccccccc} & & H & & H & & H & & \\ & & | & & | & & | & & \\ — & & C & — & C & — & C & & — \\ & & | & & | & & | & & \\ & & H & & H & & H & & \end{array}$$

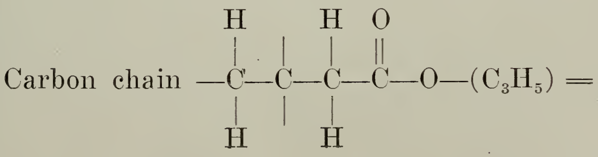
By examining these formulas it will be seen that in the paraffins all the "bonds" of the carbon atom are in use, or are saturated: in the olefines, there are two bonds in each case not in use. There is abundant experimental evidence that such is true, because we can readily cause all these compounds to take up other atoms or groups, and always to the number of the unused bonds. This leads to some very interesting possibilities which will be mentioned later. About the only other item of importance in connection with the olefines is the fact that the first is a constituent of common coal gas, and gives the yellow color to the flame when burned in an ordinary jet.

6. **Unsaturated Oils.**—It was said in a preceding section that fats containing a high percentage of olein are lower in melting point than those with a small amount of the same compound. This is because olein is itself a liquid at ordinary temperatures. By referring to the formulas it will be seen that the amount of hydrogen is proportionately less in olein than in the others, that is, it is an unsaturated compound. Representing this graphically, without trying to show the whole molecule, stearin would be thus:



$$\text{Carbon chain }-\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}-\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}-\overset{\overset{\displaystyle O}{\|}}{C}-O-(C_3H_5)=$$

in which the first part consists of a chain of seventeen carbon atoms all with hydrogen attached to saturation. Olein would be thus:



$$\text{Carbon chain }-\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}-\overset{|}{\underset{|}{C}}-\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}-\overset{\overset{\displaystyle O}{\|}}{C}-O-(C_3H_5)=$$

which shows one carbon atom with no hydrogens attached. It is possible, using some catalytic agent, more often nickel, to cause such unsaturated oils as this to take up this additional amount of hydrogen. The process is called *hydrogenation,* and is of very great commercial value. ''Crisco'' and various other fats used in cooking which are rapidly taking the place of lard are vegetable oils which have thus been hydrogenated or saturated with hydrogen. Before treatment they are yellow oils: afterwards, they are white solids. They are no more wholesome in the solid form, but the public is accustomed to solid fats instead of oils in cooking and hence the change makes them more salable. In the same way the oils of the soy bean, cotton seed, cocoanut, peanut, corn, etc., are being hydrogenated and converted into white solids. The various compound lards on the market as well as ''Cottolene,'' ''Cottosuet,'' ''White Cloud,'' etc., are all preparations containing a greater or less amount of vegetable oils.

7. **The Acetylenes.**—A third class of hydrocarbons exists, known as the acetylenes. There is only one of any importance to us and that is the first in the series, known as acetylene, with a formula of C_2H_2. It is prepared by the treatment of calcium carbide with water, thus:

$$CaC_2 + 2H_2O \rightarrow C_2H_2 + Ca(HO)_2$$

Acetylene is a valuable illuminating gas and is used extensively in suburban lighting and in the oxy-acetylene welding. For this last purpose it is burned in a blowtorch similar to the oxyhydrogen blowpipe and gives a temperature not essentially different from the other. With it rods of iron or steel are easily melted in the open air, iron plates are melted in two and various other similar operations performed.

8. **The Carbohydrates.**—In this chapter up to this time we have been studying the hydrocarbons and their derivatives. There is another class of carbon compounds of great importance, the *carbohydrates.* They contain oxygen in addition to the carbon and hydrogen and in proportions such as to form with the hydrogen a certain number of molecules of water. Thus, typical of three classes of carbohydrates, we may name

Glucose, $C_6H_{12}O_6$
Cane Sugar, $C_{12}H_{22}O_{11}$
Starch, $(C_6H_{10}O_5)_n$

which are typical of the three classes, *mono-*, *di-*, and *poly-saccharids.* In all these it will be observed that the hydrogen is double the amount of the oxygen. If we heat them strongly, the hydrogen and oxygen are expelled in the form of water, leaving a black mass of charcoal.

Glucose, as already mentioned, is manufactured from cornstarch after the oil has been removed from the grain. By the action of dilute sulphuric acid upon the starch it is made to take up another molecule of water for each group and is thus changed into sugar. It is about three-fifths as sweet as cane sugar. Usually, however, it is put on the market in the form of sirups, often under the name of "corn sirup." Naturally it is of a golden brown color, but it is sometimes bleached by means of sulphur dioxide. The colorless brand of "Karo" has been bleached in this way. While there is probably no objection to bleaching it, nothing is added to the value. There has been a popular prejudice against the use of glucose because of a hazy knowledge that sulphuric acid is used in the manufacture. This prejudice is altogether unfounded, for the acid is simply catalytic in its action, takes no part in the chemical change whatsoever and is all removed at the close of the process. The bleaching sometimes leaves traces of the sulphur gas but in the unbleached variety no sulphur acids will be found. Besides entering into most of the sirups on the market, glucose is commonly used now in making much of the candy found in the confectionery shops. The fact that it is used in the manufacture of vinegar has been mentioned elsewhere.

Cane Sugar.—Cane sugar and beet sugar have the same formula, the only difference being in their source. Milk sugar differs only in containing an additional molecule of water, really as water of combination, thus: $C_{12}H_{22}O_{11} + H_2O$. It is this sugar decomposing in the milk that produces the lactic acid, thus changing the soluble casein into the insoluble form.

Starch $(C_6H_{10}O_5)_n$.—Cellulose has the same formula as starch. It is unknown how many of these groups represented in the formula constitute the molecule. When starch is converted into glucose as already seen the catalytic agent simply causes the addition of water. From the fact that cellulose has the same composition it should seem possible to make sugar from sawdust or worn-out linen. Such a thing is possible but no process has been discovered yet whereby it may be done economically. The cellulose molecule, containing probably a greater number of carbohydrate groups, is more difficult to change.

Exercises for Review

1. What is a hydrocarbon? Name five. What are they called? Why?

2. What is marsh gas? Why so called? What is fire damp?

3. What is choke damp? After damp?

4. What hydrocarbons constitute gasoline?

5. What constitute kerosene?

6. What are chloroform and iodoform derived from?

7. What is a derivative? Illustrate.

8. Show how the alcohols may be regarded as derivatives of the paraffins.

9. What is denatured alcohol? Why made? Ethyl alcohol? Source?

10. How is grain alcohol made? Wood alcohol?

11. How is acetic acid derived from alcohol? Where is formic acid found in nature? Its antidote?

12. How is vinegar made mostly? What is glacial acetic acid?

13. How is formaldehyde obtained? What is formalin?

14. Describe formaldehyde? Give uses.

15. What ether is of interest in medicine? Why? What are ethers?

16. What is an ethereal salt? What other name for them? Name some.

17. To what class of compounds does glycerine belong?

18. Source of glycerol? What is its chief use?

19. Name four glycerol esters. What is butter? What is mazola?

20. What is oleomargarine? Give composition of a typical case.

21. How is soap made? Its by-product? What is soft soap?

22. What is the process of cleansing by soap?

23. Compare the olefines with the paraffins and state difference.

24. What is an unsaturated compound? What are olefines?

25. What is meant by hydrogenation? What effect does it have on an oil?

26. Name some hydrogenated fats.
27. How is acetylene made? Its use?
28. What is a carbohydrate? Name three.
29. How is glucose manufactured? What is corn sirup?
30. What is the purpose of the sulphuric acid in making glucose?
31. Compare cane, beet and milk sugar.
32. Compare starch and cellulose.

CHAPTER XVI

SULPHUR AND COMPOUNDS

Outline—

1. Old Ideas About Sulphur.
2. Occurrence in Nature.
    - (a) In Sicily.
    - (b) In United States.
    - (c) Method of Obtaining.
3. Purification.
4. Forms of Sulphur.
    - (a) Yellow—Flowers.
        - Brimstone.
        - Crystals, Two Varieties.
    - (b) Amorphous.
5. Properties of Sulphur.
6. Uses of Sulphur.
7. Compounds of Sulphur.
    - (a) Sulphides.
    - (b) Oxides.
        - Preparation.
        - Characteristics.
        - Uses.
    - (c) Acids.
        - Sulphuric.
            - Manufacture, Two Processes.
            - Characteristics.
            - Uses.
        - Sulphurous.
        - Fuming Sulphuric.
        - Thiosulphuric.
    - (d) Sodium Thiosulphate.
        - Uses.

Exercises for Review.

1. **Historical.**—Sulphur, from the fact that it often occurs free in nature, has been known for centuries. As stated elsewhere it was at one time regarded as a constituent of all metals, also as one of the few substances composing the human body.

2. **Occurrence in Nature.**—The oldest known deposits of sulphur are probably those of Sicily which still furnish a very large amount. Undoubtedly it is being distilled by the volcanic heat in that island all the time from compounds of sulphur at a greater or less depth in the earth so that the supply is constantly being renewed. Near the western entrance of Yellowstone Park the Sulphur Mountains consist largely of an impure sulphur which will be developed when the demand justifies it. At the present time most of the supply of sulphur used in the United States is obtained from Louisiana, at a place called Sulphur. It is said that one well there furnishes five hundred tons daily and that the total output is between twenty and twenty-five thousand tons a month. The deposit is at a depth

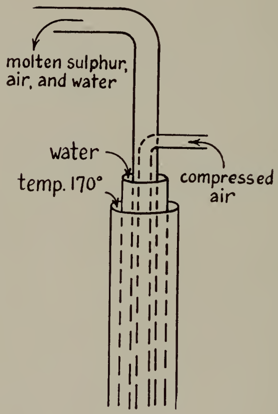


Fig. 31.—Method of obtaining sulphur in Louisiana.

of 900 feet below the surface. To obtain it a method somewhat similar to the production of salt is used. A hole several inches in diameter is drilled down to the sulphur deposit. In this are sunk four pipes, one within the other as shown in Fig. 31. The two outer ones carry down water heated under pressure to about 170° C. which is more than sufficient to melt the sulphur: compressed air is forced down the smallest of the pipes and this forces up through the second pipe the mixture of air, water and molten sulphur. It flows into large bins, about 150 by 250 feet, where the sulphur solidifies and the water runs off. The purity is such that no refining at all is necessary for all ordinary uses. When desired for shipment the solid mass is broken by blasting powder and it is then loaded into cars.

3. **Purification.**—If desired for medical purposes some further purification may be necessary. This is done by heating the sulphur in iron retorts to its boiling point and condensing the vapors in a cool chamber. Usually one distillation is sufficient. For some purposes this product is washed with water and dried before further use.

4. **Forms of Sulphur.**—Although oxygen is a gas and sulphur a solid at ordinary temperatures, they belong to the same family of elements. We have seen that oxygen occurs in two forms, the ordinary and ozone, its allotrope. In the same way sulphur occurs in more than one form, yellow and amorphous. There are three or four varieties of the yellow: *flowers*, *brimstone* or *roll*, and two forms of crystals, *rhombic* (octahedral) and *monoclinic* (needle-like). Flowers of sulphur is obtained when sulphur is boiled and the vapors condensed, as mentioned in purifying it for medicinal purposes; if the flowers is melted and poured into moulds

it is known as brimstone; while the two crystalline forms are obtained by two different methods. Sulphur dissolves readily in carbon disulphide: if this solution is permitted to evaporate slowly the octahedral crystals are formed, which are the stable variety. When found in nature as they often are they are always of this system. Beautiful crystals may be obtained in the laboratory by making a solution of sulphur in carbon disulphide in a beaker and tying tightly over it two thicknesses of filter paper. This causes a slow evaporation of the liquid and a growth of crystals of considerable size. (See Fig. 32.)

Monoclinic Sulphur.—The needle-shaped crystals may be made by carefully melting sulphur, not allowing it to become heated much above its melting point, and pouring upon a filter paper in a glass funnel. Sufficient sulphur should be used to fill the funnel at least half full. As soon as the crystals, which can be seen forming rapidly after the process begins, have nearly covered the surface, the funnel should be inverted and the portion still liquid poured out. The long, needle-like crystals, which have grown out from the sides can then be readily seen. They are not a very stable variety and eventually break up into the rhombic form.

Fig. 32.—Sulphur crystals.

Plastic or Amorphous Sulphur.—If sulphur is heated to 250° C. and then cooled suddenly by pouring into cold water, it becomes a dark, nearly black, solid, soft like rubber, which may be stretched out with ease. In making the experiment it is well to heat the tube containing the sulphur until boiling begins, otherwise, we may not have reached the necessary temperature. This form is very unstable. Left in the air, in a few days it loses its dark color and has begun a slow change back to the yellow variety. At room temperatures, however, it requires months and some say even years for the transformation to be complete. If kept at the temperature of boiling water an hour is sufficient to effect the complete change.

5. **Properties of Sulphur.**—The yellow varieties of sulphur have a melting point of 114.5° C. At this temperature and a little above, the liquid is a pale yellow color, thin, almost as water: as the temperature rises, the liquid becomes darker in color and thicker until 160° C. is reached when it is decidedly viscous and can not even be poured from the test tube. Again as the temperature rises it becomes thin and at 448° begins to boil. The rhombic variety has a density just a little more than twice that of water. The yellow varieties are all readily soluble in carbon disulphide, the amorphous not. None of them is soluble in water and all are without taste or odor.

6. **Uses of Sulphur.**—There was a time when a mixture of sulphur and molasses was regarded as almost a necessity in the spring as a tonic. It is still used in salves somewhat for its germicidal properties. Boiled with lime it is extensively used by horticulturists now as a spray on peach, plum and other trees to prevent dry rot and destroy other fungous diseases. It is also used extensively in the manufacture of rubber goods. Without the sulphur, rubber becomes unduly soft in

warm weather and very hard and brittle in cold; sulphur prevents this, through some change not understood. With a larger amount of sulphur and a higher temperature out of contact with the air, the rubber becomes hard and brittle and is known as vulcanite. In this form it is used extensively for making combs, electrical insulators, telephone mouthpieces and receivers, phonograph records, plates for false teeth, fountain pens and a large variety of other things. The black color in most of these articles is caused by the admixture of small amounts of lampblack. If a pink color is desired, vermilion is added. Vulcanite may be made to resemble tortoise shell and is sometimes sold in imitation of the real article. Considerable quantities of sulphur are used in the preparation of sulphur dioxide, for purposes which will be given under another topic.

7. **Compounds of Sulphur.**—*Sulphides.*—It has been mentioned that sulphur and oxygen belong to the same family of elements. We have seen that oxygen combines with all other of the commoner elements except fluorine: likewise sulphur combines with a very large number of the elements and being negative, with all metals except gold and platinum. With many of these the action may be made to take place in a test tube, by mixing the filings of the metal with sulphur intimately and heating strongly. As the chemical action proceeds a bright red glow passes through the mass. In nature nearly all metals are found in combination with sulphur as sulphides and they form many of the common ores from which the metals are obtained.

Hydrogen Sulphide, H_2S.—This is a gaseous compound often found dissolved in spring and artesian waters. It is supposed to have therapeutic values though that is very doubtful. It is a colorless gas, of intensely offensive, nauseating odor, like that of rotten eggs, which give off this gas in abundance; considerably soluble in water, will burn with a pale blue flame, which will deposit the sulphur upon a cold dish held close up against the flame: burning freely in the air it produces steam and sulphur dioxide, the latter of which may be recognized by its suffocating odor. It is very poisonous, producing dizziness, unconsciousness and ultimately death. However, less than one-half of one per cent in the air is not attended by serious results; as its odor is so intense, the most minute portions warn of its presence, hence there need be no reason for uneasiness regarding it. The best antidote is very dilute chlorine which may be obtained by adding a little hydrochloric acid to a bleaching powder solution.

Uses of Hydrogen Sulphide.—To the analytic chemist hydrogen sulphide is indispensable. It is his means of precipitating a very large number of metals and furnishes the basis for their separation into groups and subsequent identification. When using it, precautions should always be taken to furnish means of carrying off the portions escaping from the liquid. For this use, it is generally prepared by treating ferrous sulphide with either dilute sulphuric or hydrochloric acid. The reaction is given below:

$$FeS + H_2SO_4 \rightarrow FeSO_4 + H_2S$$
$$FeS + 2HCl \rightarrow FeCl_2 + H_2S$$

When hydrogen sulphide burns the reaction is

$$2H_2S + 3O_2 \rightarrow 2H_2O + 2SO_2$$

Oxides of Sulphur.—There are two oxides of sulphur, the dioxide with formula, SO_2 and the trioxide, SO_3. The first is always obtained when sulphur is burned in the air or when most sulphides are heated strongly under like circumstances.

Sulphur Dioxide.—When this compound is desired for experimental work in the laboratory it is generally obtained by heating concentrated sulphuric acid with either copper turnings or with charcoal. We have seen that zinc with dilute sulphuric acid sets free hydrogen from the acid, but by referring to the order of the metals as regards electropositive character, shown on page 40 it will be seen that copper is less positive than hydrogen, hence could not set free the hydrogen. It will be found that concentrated acids act differently from diluted ones; so while sulphuric acid will not set free its hydrogen when put with copper, when concentrated and hot it will give up part of its oxygen. This is what happens:

$$H_2SO_4 + Cu \rightarrow CuO + H_2SO_3$$
$$H_2SO_3 \rightarrow H_2O + SO_2$$

H_2SO_3 is sulphurous acid and is very unstable, hence the second reaction given above rapidly follows the first. A third reaction follows in which the copper oxide formed is dissolved by other portions of sulphuric acid present, thus:

$$CuO + H_2SO_4 \rightarrow CuSO_4 + H_2O$$

So, our final products are sulphur dioxide, copper sulphate and water.

Characteristics of Sulphur Dioxide.—Sulphur dioxide is a colorless gas, very soluble in water, so much so that it must be collected by *downward displacement* in the laboratory and not over water. It is of very irritating, suffocating odor; will not burn, or permit of the combustion of other substances; is acidic in character; strongly germicidal and a slow bleaching agent.

Uses of Sulphur Dioxide.—It has been used extensively for fumigating buildings: this has generally been accomplished by burning in the various rooms or at some place where the ventilating system would carry the gas to all the rooms, sulphur candles. As formaldehyde may be had so much more quickly and is probably much more effective, it is rapidly displacing sulphur dioxide as a fumigating agent. It is used extensively for bleaching fruits and some other food products, as already mentioned in the case of many sirups on the markets. At most of the larger grocery stores may be found dried apples, in flat annular slices nearly white in color. It is well known that when an apple or most any other fruit is cut and exposed to the air, it turns brown. In drying fruit by artificial heat in evaporators, as is done in many places, as often as fresh trays of fruit are put into the evaporator small quantities of sulphur are placed in a cup on the furnace, where the sulphur catches fire and burns. The dioxide produced, prevents the formation of the brown color, until the fresh fruit has been seared over on the surface, after which it remains white. In sections of our country where rain does not fall in the fruit season the drying is done in the open air. To prevent the attack of the fruit by various insects it is found necessary to ‘‘sulphur’’ the fresh fruit. It is cut, spread upon galvanized wire trays, and placed in a chamber into which are passed sulphur dioxide fumes. At the end of a certain length of time it is removed and placed in the open air to dry. Small portions of the sulphur are left in the fruit in the form of sulphites, mostly, but as there seems no other way to prevent the destructive attacks of insects the government has not forbidden the use. It is probable that the amount of sulphite is so small as not to be injurious.

Uses in Bleaching.—We have already seen that chlorine and hydrogen peroxide are used for bleaching. For certain substances as wool, silks and straws, most of which are slightly yellow in nature, chlorine is not suited at all, because it would be utterly destructive. Hydrogen dioxide is better for some of these, but not as desirable as sulphur dioxide. It will be remembered that the other agents accomplish the bleaching through the oxygen which is set free: sulphur dioxide is believed to work in just the opposite manner, that is, by *deoxidation,* or *reduction.* It has the power of removing oxygen *from* other substances because of the fact that it is an unsaturated compound. Whether it removes the oxygen from the coloring matter in the natural substance or reduces it in some other way we are not sure; but at any rate the reducing action produces a colorless compound. It is noticed, however, that straws, woolens and silks, as they are used and exposed to sunlight and air all become yellow again. This is believed to be due to the effect of the oxygen of the air in changing the compound back again to the condition before it was bleached.

Acids of Sulphur.—There are several acids of sulphur known to chemists but only one of very great importance commercially. That is sulphuric. Sulphurous acid, H_2SO_3, has been mentioned as a very unstable body, hence is not an article of commerce. Its anhydride, sulphur dioxide, since it is easily liquefied, may be purchased in heavy glass siphon bottles.

Sulphuric Acid, H_2SO_4.—This acid has been known for centuries and was prepared by distilling ferrous sulphate, known as green vitriol. On account of this fact it was formerly called oil of vitriol. It is now manufactured by two processes, known as the *chamber process,* and the *contact process.* Each has its advantages although the second method is the cheaper. In both, sulphur dioxide is the starting point; as this gas is a waste product from most of our great western smelters it should be used for making sulphuric acid, but is mostly allowed to escape into the air.

The Chamber Process.—In this country the sulphur dioxide needed is more often obtained by roasting iron pyrite, largely imported from Spain or elsewhere. This is passed into chambers where it meets nitric acid vapors and this reaction takes place:

$$3SO_2 + 2HNO_3 \rightarrow 3SO_3 + 2NO + H_2O$$

Steam is introduced and also currents of air: the steam reacts with the sulphur trioxide being formed, producing sulphuric acid.

$$SO_3 + H_2O \rightarrow H_2SO_4$$

At the same time the oxygen of the air reacts with the nitrogen dioxide formed and it is again changed into nitrogen peroxide, thus:

$$2NO + O_2 \rightarrow 2NO_2$$

Immediately this peroxide reacts with more sulphur dioxide, thus:

$$NO_2 + SO_2 \rightarrow NO + SO_3$$

And then the preceding reaction is repeated indefinitely. It will be seen, therefore, that the nitrogen oxide is merely an agent, catalytic, for transferring the oxygen of the air to the sulphur dioxide. It is one of the few cases of catalytic action where we know exactly what the process is. It would appear that a very small amount of nitric acid to furnish the original nitrogen oxide would be sufficient for an indefinite time, but it must be remembered the air is four-fifths nitrogen and in removing this from the chambers, gradually the oxide escapes also: but the loss is very slow as means are taken to prevent it. The details probably are beyond a book of this size. Fig. 33 will, however, give some idea of the process. The acid thus obtained is known as *chamber acid* and may safely remain in the chambers until it reaches a strength of 80 per cent when it begins to attack the lead-lined walls and floors. It must then be removed, after which it is concentrated by boiling in platinum or other vessels or used in the contact process as will be described later.

The Contact Process.—By this method platinum is used as the catalytic agent. It might be supposed that a stream of air and heated sulphur dioxide passed through a tube would combine, but such is not the case. However, it is found that platinum will cause such a union, as we have seen it will do between hydrogen and oxygen even in the cold. Accordingly in order to spread a small amount of platinum which is very expensive over a very great surface asbestos is dipped in platinum chloride solution and heated. The chlorine is expelled and the platinum remains in a very finely divided form upon the asbestos. This is placed in a suitable tube, is heated and a stream of sulphur dioxide and air passed through it. Owing to the catalytic action of the platinum the oxygen and sulphur dioxide unite forming the trioxide, which though a solid is very volatile at the temperature of the tube. This is passed on into sulphuric acid of about such strength as that mentioned derived from the chamber process, when the two unite producing ultimately a white crystalline solid known as *fuming* sulphuric acid and the variety best suited for many purposes. Theoretically the trioxide might be passed directly into water, but when this is done great heat is produced such that considerable portions of the trioxide are volatilized and lost. This does not happen when somewhat concentrated acid is used as described.

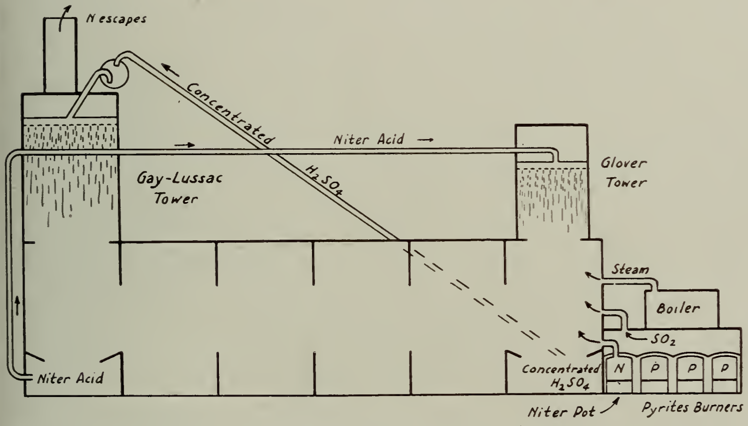


Fig. 33.—Chamber process for sulphuric acid. The escaping gases pass up the Gay-Lassac tower where they meet the streams of sulphuric acid. This combines with the nitrogen oxide present, forming the niter acid, so called. This is pumped to the top of the Glover tower, where, descending, it meets the steam, which decomposes it. The nitrogen oxide then begins its work all over again.

Characteristics of Sulphuric Acid.—Sulphuric acid is a colorless liquid, when pure, with a specific gravity of 1.84 and oily in appearance. It is exceedingly hygroscopic and when water is added great heat is produced. In mixing the two water should never be poured into the acid, but the reverse and very slowly, in order that the water may take up the heat. In the proper amounts water may be brought almost to the boiling point and if the water is added to the acid rapidly, the heat may produce sufficient steam to eject portions of the acid upon the person of the operator with serious results. On account of this property sulphuric acid serves as an excellent drying agent for gases, accomplished by allowing them to pass slowly through it. On wood and sugar it serves to remove the hydrogen and oxygen present in the carbohydrates, leaving a charred mass; certain invisible inks are simply very dilute sulphuric acid which upon heating loses its water, becomes concentrated and chars the paper as just stated. As we have seen with metals in the electromotive series above hydrogen, it gives up its hydrogen, especially when diluted, for the metal; with metals less positive than hydrogen it only reacts in the concentrated condition and when heated, and then as an oxidizing agent, that is, it gives up a part of the oxygen, converting the metal into an oxide. Its boiling point is 330° C. but at this temperature it is largely decomposed forming trioxide and water. The fuming sulphuric is a crystalline solid, being really pure sulphuric saturated with sulphur trioxide, with the formula, $H_2S_2O_7$. It fumes from the fact that the trioxide is escaping and combining with the moisture of the air, condensing it into minute globules just as it has been said hydrogen chloride does.

Uses of Sulphuric Acid.—It is said the civilization of a nation may be judged by the amount of sulphuric acid it uses. Certainly it is the most used of all the acids. It is necessary for the manufacture of practically all other acids as well as many other chemicals. It is used extensively in making fertilizers from bones and native phosphate rocks; for various explosives which we have already studied and for refining petroleum in removing some of the tarry products which discolor the oils.

Sodium Thiosulphate, $Na_2S_2O_3$.—This is a compound of the theoretic thiosulphuric acid, $H_2S_2O_3$. It is really sulphuric in which an atom of sulphur has taken the place of one of oxygen. The salt is sold frequently under the name of "hypo" or sodium hyposulphite, though wrongfully. It is used by photographers in fixing photographic plates and prints and as an antichlor in removing the last traces from cloth of the chlorine used in bleaching them.

Exercises for Review

1. What was the old idea of sulphur as related to the human body and to metals?
2. What is one of the oldest known deposits of sulphur? What is probably their origin?
3. Where is the best deposit in this country? How is it obtained here?
4. What other large deposit in the United States?
5. How may sulphur be purified for medical purposes?
6. Name the varieties of sulphur and describe each.
7. How are rhombic crystals made? Monoclinic crystals?
8. Which is the most stable form? How does it occur in nature?
9. How is plastic sulphur made? How different from the yellow variety?
10. Give a medical use for sulphur; a horticultural use; two other uses.

11. What is vulcanite? Give several uses.

12. What is a sulphide? How may metal sulphides be made?

13. Name two sources of hydrogen sulphide in nature?

14. Give chief properties of hydrogen sulphide.

15. What are physiologic effects of hydrogen sulphide? Its antidote?

16. Of what use is hydrogen sulphide to the chemist?

17. Name the oxides of sulphur and give formulas.

18. How is sulphur dioxide made in the laboratory? How is the action different from that seen with other metals? How are the conditions different?

19. Describe sulphur dioxide.

20. Name one medical use of sulphur dioxide; three commercial uses.

21. Describe its use in drying fruit. How does it bleach? To what goods is it applied? Why do they return to their original color?

22. Name four acids of sulphur and give formulas of each.

23. What two processes of making sulphuric acid? What is the catalytic agent in each case? How does it act in the chamber process?

24. What kind of acid is obtained by the contact process?

25. Describe sulphuric acid. Why is invisible ink made of it not visible before heating? Why visible afterward? Will it become invisible again?

26. Give several important uses of sulphuric acid.

27. What is hypo? Give its uses.

CHAPTER XVII

THE NITROGEN FAMILY

Outline—

1. Names of Members of the Family.
   Why Classed Together.
2. Phosphorus.
   - (a) Discovery.
   - (b) Occurrence in Nature.
   - (c) Manufacture.
   - (d) Forms of.
   - (e) Comparison of Varieties.
   - (f) Uses of Each Variety.
3. Matches.
   - (a) Kinds.
   - (b) Composition.
4. Phosphate Foods.
   - (a) Necessity.
   - (b) How Manufactured.
5. Fertilizers.
6. Arsenic.
   - (a) History of.
   - (b) Occurrence.
   - (c) Properties of.
   - (d) Uses as a Metal.
   - (e) Compounds.
   - (f) Arsenic Poisoning.
   - (g) Tests for Arsenic.
   - (h) Treatment in Poison Cases.
7. Antimony.
   - (a) Description of.
   - (b) Uses of Antimony.
   - (c) Compounds of.
8. Bismuth.
   - (a) Properties of.
   - (b) Uses.
   - (c) Compounds of Bismuth.

9. Comparison of Members of Family.
Table of Compounds.
Exercises for Review.

1. **Members of the Nitrogen Family.**—Practically all of the eighty elements known arrange themselves into families as we have seen the four halogens do. In the nitrogen family, besides this one already studied in connection with the air, there are phosphorus, arsenic, antimony and bismuth. They are all solids except the first and taken as a whole are not strikingly alike in physical properties: but their chemical behavior and their compounds, as well as other considerations, make it certain that they should be classed together.

2. **Phosphorus.**—Phosphorus was discovered in 1669 by Brand. It received the name phosphorus, meaning *light bearer*, because it glows in the dark when exposed to the air. It is found in nature in the bones and teeth, in the form of calcium phosphate constituting about three-fifths their weight. In much smaller amounts it is found in the muscles in a complicated compound called lecithin and in the nerve centers. It is said that the sum total in the average human body would amount to somewhat more than three pounds, of which about 90 per cent is in the bony structure; about 9 per cent in the muscles and 1 per cent in the brain and nerve centers. In some of the southern states, notably South Carolina, Florida and Tennessee, it is found in extensive deposits of calcium phosphate, $Ca_3(PO_4)_2$.

Manufacture.—Phosphorus may be made either from bones or the native phosphate rock. At present it is mostly obtained from the native rock. This is mixed with silica, SiO_2 and charcoal or coke, and fed into an electric furnace. The heat causes the phosphorus to distill out as a vapor after which it is condensed under water, while the calcium silicate runs off as a slag from an opening at the bottom of the furnace. The essential features are shown in Fig. 34.

Forms of Phosphorus.—Like oxygen, carbon and sulphur, phosphorus occurs in more than one form. Corresponding to roll sulphur we have the waxy phosphorus, sometimes called yellow or white phosphorus; besides this, corresponding to amorphous sulphur is the red phosphorus or amorphous. Each is convertible into the other under different circumstances. Under water in bright sunlight the yellow slowly changes into the red variety; in a vessel containing no oxygen heated to about 250° C. the change is rapid. On the other hand if the red is heated to 300° C. and the vapors passed into water they condense again as the yellow variety.

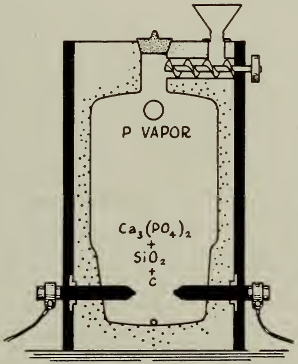


Fig. 34.—Manufacture of phosphorus.

Comparison of the Two Varieties.—The waxy variety is of a very pale amber color when fresh but becomes yellower on exposure to light; the amorphous is of a dark reddish brown color. The yellow is soluble in carbon disulphide, the red is not. The yellow is very poisonous, the other not. Taken internally one-sixth of a gram is a fatal dose oftentimes. Continual inhalation of the vapors produces a disease known as "phossy jaw" which is really a necrosis of the jaw bones and is usually incurable. The yellow gives off a peculiar odor, the other none; yellow catches fire at 50° C., the other about 250; the one is luminous in the dark, the other not.

Uses of Phosphorus.—Small amounts of phosphorus are employed in the manufacture of poisons for rats, mice, roaches and other vermin. The bulk of it, however, is used in making matches. Of these there are two varieties. Originally matches were made by dipping the pine splints into molten sulphur and then tipping with a small amount of phosphorus mixed with some glue or other cementing material which protected it from the air. These are known as sulphur matches but are seldom seen at present except in certain portions of the country. They are very slow in getting started and moreover, give off sulphur dioxide, both of which reasons have led to their being discarded. Later paraffin was substituted for the sulphur as kindling for the splint, and to the head was added potassium chlorate or some other oxidizing material. These were rapid in their action and gave no offensive gas, but they were so easily ignited that many fires resulted. Moreover, children were often poisoned by them and the workmen in the factories were continually subjected to the fumes. Most countries passed laws against the manufacture of such matches and in the United States in 1913 they were taxed out of existence, two cents being levied upon each hundred. At the present time therefore, the ordinary match has the paraffin for kindling, and in the head, a phosphorus compound with some oxidizing material and glue or dextrine to make it adhere. The friction produces sufficient heat to decompose the phosphorus compound and ignite the paraffin.

3. **Safety Matches.**—In the safety match the phosphorus of the red variety, mixed with some antimony trisulphide, is upon the box, while upon the match head is some oxidizing material like potassium chlorate, with antimony trisulphide and glue or dextrine. It is only by great friction that the match may be ignited without rubbing on the prepared surface; but when drawn over the box, a tiny amount of the red phosphorus is converted into the yellow variety, catches fire and ignites the head of the match.

Other Uses.—In the form of compounds phosphorus is essential both to plants and animals. Virgin soils as a rule are rich enough in phosphate for plant growth, but continued cropping, especially of grains, like wheat, removes it to such an extent that it must be restored by artificial means. Likewise the human body must have the phosphates for the proper nourishment of the bones, teeth and nerve centers. Of cereals wheat if used whole is the richest in phosphates; the legumes, beans and peas, are also rich in phosphates, likewise the yolk of eggs.

4. **Fertilizers.**—The native phosphate rock as well as the bones are not soluble in water, hence not available as plant food. To render them suitable for fertilizer they are treated with sulphuric acid which changes them into what is known as the superphosphate, $CaHPO_4.H_3PO_4$ often written $CaH_4(PO_4)_2$. The byproduct formed when this is done is a calcium compound of same composition as gypsum and this is left mixed with the superphosphate. Considerable amounts

of soluble phosphate are also obtained in preparing steel from phosphorus-bearing ores.

6. **Arsenic, As.**—In order of density, the next element in the nitrogen family is arsenic with an atomic weight of 75. It has been known since the middle ages although at that time it probably had never been isolated. Its compounds were known and the fact had been observed that like mercury they had the power of turning a bright piece of copper silvery in appearance; this was one of the reasons offered for the belief that copper could be changed into silver.

Arsenic in Nature.—Arsenic occurs with many sulphide ores of the metals and is often obtained as a by-product in their preparation. It is perhaps most often prepared from a sulphide and arsenide of iron, FeAsS.

Description of Arsenic.—It is of a bright, steel gray color, but is usually tarnished so that it appears almost black. By heating in an open dish this dark coating soon disappears and the real color of the arsenic is seen. It vaporizes without melting and burns in the air when ignited, with a bluish white flame, producing the trioxide. It is crystalline in structure and very brittle.

Uses of Arsenic.—In small amounts, about one-half of one per cent, it is mixed with lead in making shot. There are three reasons for this, the main one being that it gives greater fluidity to the melted mixture than lead alone has, so that when the alloy is poured from the top of a high tower, the shot become much more perfect than they would otherwise. A second reason which adds to the same end is that the melting point of the alloy is lower than that of lead and the mixture does not solidify so quickly, hence the drops have more time to become perfectly round. Third, the shot is somewhat harder for the small admixture of arsenic.

Arsenic Trioxide, As_2O_3.—This compound is sold at drug stores under several names, white arsenic, arsenous acid and even "arsenic." It is usually in the form of a white powder, is somewhat soluble in water, has a slightly sweetish taste, and is very poisonous. It is used somewhat in taxidermy to protect the skins against attacks of insects, as a common poison for vermin, and to some small extent in medicine as a tonic, in the form of Fowler's solution.

Antidote for Arsenic Poisoning.—Probably the best antidote is ferric hydroxide, freshly prepared. This is made by adding dilute ammonia water to a ferric chloride solution and washing the precipitate to remove any excess of ammonia. Ferric hydroxide is a reddish brown, gelatinous precipitate as thus obtained and with the arsenic forms in the stomach an insoluble compound so that it is not absorbed by the system. This should be followed by an emetic or the use of the stomach pump. If for any reason ferric chloride can not be obtained magnesia stirred in water may be taken instead. It acts as does the ferric hydroxide though perhaps less rapidly.

Tests for Arsenic.—There are several tests which may be made, some of them very simple. What is known as Reinsch's is one of the easiest made. A few cubic centimeters of the arsenic solution are put into a test tube, some pieces of bright copper added and then some strong hydrochloric acid. The mixture is boiled for two or three minutes. The copper becomes silver colored if arsenic is present. Mercury compounds may give the same result, so in order to distinguish between them, the copper is taken from the tube, dried carefully, placed in a dry test tube and heated strongly. If the deposit is arsenic, a white ring will appear on the cooler portion of the test tube, crystalline in character. Sometimes these crystals are very small so that they can not be detected by the naked eye, but they will sparkle as a rule held in sunlight. If the silver coloration is due to mercury, the ring forming upon the cooler portion of the tube will be made up of tiny drops of mercury and not crystalline.

Marsh's Test.—This is by far the most delicate and is generally used in postmortem examinations. Various forms of apparatus are used but one of the simplest is shown in Fig. 35. The flask is prepared for the generation of hydrogen from sulphuric acid by means of *arsenic-free* zinc. To be sure the zinc is pure it is tested thus: when the gas has been flowing long enough to remove all the air, and this is important, as the air mixture is very explosive, the jet is lighted. A cold dish is held against the flame. If the zinc is arsenic-free no spot appears upon the dish no matter how long held there. Next the arsenic solution is added through the thistle tube; the color of the flame, if arsenic is present in considerable amounts, changes from yellow to a pale lavender, and upon a cold porcelain dish held against the flame, a brownish-black spot with metallic luster is formed. Antimony compounds make a similar spot, darker in color, more velvety in appearance, not soluble in a bleaching powder solution, while the arsenic spots are. This test it is said will detect the minutest portions of arsenic, even one part in several hundred thousand of water. The chemical reactions taking place are thus shown:

$$Zn + H_2SO_4 \rightarrow 2H + ZnSO_4$$

$$H_3AsO_3 + 6H \rightarrow H_3As + 3H_2O$$

The hydrogen arsenide, formed in this second equation, also called arsine, is the most poisonous of the arsenic compounds: being a gas, care should be taken not to inhale it before lighting the jet, as small quantities are sometimes dangerous.

$$2H_3As + 3O_2 \rightarrow 3H_2O + As_2O_3$$

This equation shows the reaction when the dish is not against the flame. The white fumes seen floating off into the air are arsenic trioxide. When the dish is against the flame, they disappear as shown by the following equation:

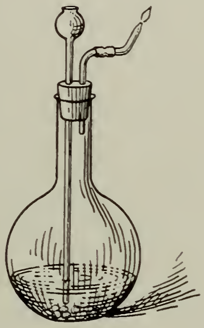


Fig. 35.—Marsh's test for arsenic.

$$4H_3As + 3O_2 \rightarrow As_4 + 6H_2O$$

The brown spots are the arsenic shown in the equation.

Paris Green, $Cu(C_2H_3O_2)_2 . CuHAsO_3$.—It will be seen from the formula that Paris green is a compound of copper and arsenic. It is bright green in color and was formerly used as a pigment, but on account of its very poisonous properties its place has been taken by coal tar products. Its chief use now is as an insecticide, especially for the Colorado potato beetle.

7. **Antimony, Sb.**—Antimony ranks next to arsenic in density, atomic weight, 120.2. It is a lustrous, steel white metal, does not tarnish in the air, highly crystalline in structure and very brittle. Its physical properties, therefore, are those of a metal; its chemical properties are more nearly like those of the electronegative elements.

Uses of Antimony.—When finely powdered it is black in color and is often used in rubbing upon plaster casts to give them the appearance of old bronze. Its most abundant use is for the manufacture of alloys such as type metal. This alloy contains tin, lead and antimony. The antimony gives hardness to the mixture and causes expansion upon solidifying. If type were made of lead alone, as it contracts when it solidifies, as most substances do, the metal would withdraw from all the details of the mold and the type would not produce legible letters. Antimony causes a decided expansion so that when the type metal solidifies it fills every crevice no matter how small and gives clear, sharp type. It is also used in making Babbitt metal as well as many other alloys.

Compounds of Antimony.—Antimony forms compounds like those of arsenic. Several of them were at one time used in Europe for medicine, but being very poisonous, many deaths resulted and laws were passed forbidding such use. Some are still used in veterinary medicine. The tartrate, $KSbOC_4H_4O_6$, known as tartar emetic, is used to some extent as an emetic. The sulphide, Sb_2S_3, is used in match heads as stated elsewhere in this chapter and to some extent in fireworks.

8. **Bismuth, Bi.**—Its atomic weight is 208, hence by far the heaviest of the nitrogen family. Like arsenic and antimony it is crystalline in structure, and very

brittle; it also expands on solidifying. Its color is darker than that of antimony with a golden or purplish luster, depending on how the light strikes it.

Uses of Bismuth.—On account of its expansibility on solidifying it is used for the same purposes as antimony, but being much more expensive than antimony is employed only for the more delicate castings and stereotypes. On account of its imparting low fusing point to alloys it is often used to make plugs and fasteners for protection against fire. In automatic sprinkling systems in large department stores and elsewhere, the stoppers in various openings in the water pipes are held in position by plugs of a bismuth alloy. Even a small fire will melt these, the water pressure will then force out the stopper and automatically the water is turned on. In boilers a similar device is used to prevent explosions. Fire doors, made of iron are often propped open by such fusible plugs: when melted away the door closes by means of a spring and the fire is confined to the single room. Metal booths for moving picture machines have the openings provided in a similar way for automatically closing. A link in the chain which holds the shutter open is made of fusible metal; when this is melted the shutter closes by its own weight and the fire is kept within the booth. Wood's metal which is an alloy of bismuth has a melting point of only 60° C., which is lower than the temperature of a cup of hot coffee.

Compounds of Bismuth.—Only one is of special importance and that because of its use in medicine. The subnitrate, formula, $BiONO_3$, also called the oxynitrate, is made from the ternitrate by treating with water and washing the precipitate. Thus:

$$Bi(NO_3)_3 + H_2O \leftrightarrows BiONO_3 + 2HNO_3$$

It is a white powder, used as a cosmetic to prevent chapping of the skin, especially with small children, and as a remedy for certain stomach and intestinal troubles.

9. Comparison of the Members of the Nitrogen Family.—The following table gives an idea of the various compounds of the members of this family and shows how closely they resemble in this respect. While they may differ materially in their outward aspect, or physical properties, their compounds are strikingly similar.

TABLE FOR COMPARISON

	NITROGEN $N = 14$	PHOSPHORUS $P = 31$	ARSENIC $As = 75$	ANTIMONY $Sb = 120$	BISMUTH $Bi = 208$
Hydrogen Compound	Ammonia NH_3	Phosphine PH_3	Arsine AsH_3	Stibine SbH_3	None ——
Oxides	N_2O_3 N_2O_5	P_2O_3 P_2O_5	As_2O_3 As_2O_5	Sb_2O_3 Sb_2O_5	Bi_2O_3 Bi_2O_5
Chlorides	NCl_3	PCl_3	$AsCl_3$ (?)	$SbCl_3$	$BiCl_3$
Oxychlorides	NOCl	POCl		SbOCl	BiOCl
Acids	HNO_3 ——	HPO_3 H_3PO_4	—— H_3AsO_4	—— H_3SbO_4	None ‘‘

Exercises for Review

1. Give the names of the nitrogen family. Why are they classed together?
2. When was phosphorus discovered and by whom?
3. State where phosphorus is found in the human body and in what form?
4. What amounts of phosphorus are found in the body?
5. How is phosphorus manufactured and collected?
6. Name the varieties of phosphorus and compare with corresponding ones of sulphur.
7. Compare red and yellow phosphorus in six particulars.
8. What is ‘‘phossy jaw’’? What is the cause?
9. Give two uses for phosphorus. Would the red variety do for the first?

10. How was the oldest match made? What objection to it?

11. What objection to the "parlor match" of a few years ago?

12. What is the composition of the ordinary match now?

13. How is the safety match different from the ordinary?

14. How is phosphorus supplied artificially to plants? What is the source of this fertilizer? How made?

15. How is phosphorus supplied to the human body? Name some good foods for this purpose.

16. How long has arsenic been known to scientists? Give some historical facts in connection with it.

17. What are the most important properties of arsenic?

18. Give one use for arsenic and three reasons for such use.

19. What is arsenous acid? Give characteristics and uses.

20. What are two antidotes for arsenic poisoning? How prepared for use?

21. Describe Marsh's test for arsenic. What can be said of its delicacy?

22. Describe Reinsch's test for arsenic. How distinguished from mercury?

23. What is the composition of Paris green? What is its main use?

24. Give chief properties of antimony.

25. What are some of the uses of antimony? Give reason for such uses.

26. Describe bismuth.

27. What is the chief use of bismuth? What properties do its alloys have?

28. Give some valuable uses of fusible alloys. What is melting point of one?

29. Name one valuable compound and give use of it in medicine.

30. Compare the members of this family as to hydrogen compounds formed; as to oxides; chlorides; acids.

CHAPTER XVIII

SILICON AND COMPOUNDS

Outline—

1. Natural Compounds of Silicon.
    (a) Silicon Dioxide, Silica.
    (b) Silicates.
2. Water Glass.
    (a) How Made.
    (b) Uses.
3. Window Glass. Crown Glass.
    (a) Preparation.
    (b) Properties.
    (c) Uses.
4. Bohemian Glass.
    (a) Composition of.
    (b) Properties.
    (c) Uses.
5. Flint Glass.
    (a) Composition.
    (b) Characteristics.
    (c) Uses.
6. Manufacture of Glass Articles.

Exercises for Review.

1. **Natural Compounds.**—As shown by Fig. 9 on page 57 silicon constitutes about one fourth of all the material of the earth. It does not occur free but certain compounds are very abundant and widely distributed. One of the most abundant is common sand, silicon dioxide, formula SiO_2. Many varieties of this compound are familiar. In transparent hexagonal prisms it is known as rock crystal; crystallized or not we have rose

quartz, smoky quartz, milky quartz, or amethyst, named from their color. Agate is mostly petrified wood in which silica has slowly replaced the cellular structure of the tree, preserving the rings of growth more or less perfectly and showing different colors as different foreign matter has been introduced from time to time. A very large number of rocks are silicates, such as the felspars, kaolin, the clays, etc.

2. **Water Glass.**—Silica is not soluble in water or any of the common acids; but when fused with sodium carbonate it reacts as shown by the equation:

$$SiO_2 + Na_2CO_3 \rightarrow Na_2SiO_3 + CO_2$$

Sodium silicate thus prepared is a nearly colorless, flint-like looking compound, with few uses. If instead of boiling dry to obtain the solid, it is left in the form of a solution, as is usually done, it has about the consistency of glycerine, and if pure not specially different in appearance. It is thus sold under the name of *water glass* and has manifold uses. For the manufacture of paper boxes and in many similar places where glue was formerly used, water glass is now being substituted, being cheaper. It is also used as a cementing material in many ways; and mixed with nine parts of water it is recommended as a preservative for eggs. The solution is poured into a jar and the eggs added as obtained. They should be covered by the solution and the jar kept covered to avoid excessive evaporation. It is probably the best method known of preserving eggs, as they will keep reasonably well for nine to twelve months. The solution fills the pores of the shell and prevents germs causing decomposition from entering.

3. **Window Glass.**—This is a cheap variety of glass

formed by fusing together lime, sodium carbonate and silica. The resulting product is a sodium calcium silicate, not soluble in water as is the sodium silicate just studied. It is usually greenish in color due to the presence of small quantities of iron compounds. This may be removed largely by adding a small amount of manganese dioxide at the time of fusing the mixture. Any excess of the manganese will give the glass a violet tinge a small amount of which is not objectionable. This variety of glass has a comparatively low melting point and may be readily softened in the Bunsen burner. It is used for making test tubes and most of the glass tubing for the laboratory because of the fact that it may be bent into all sorts of shapes as occasion may demand. It is often called *crown glass.*

4. **Bohemian Glass.**—If potassium carbonate is substituted for the sodium carbonate in crown glass we have produced what is known as *Bohemian glass.* It is more transparent than crown, less easily attacked by laboratory reagents, and of much higher melting point. It is used therefore for combustion tubes, which are often subjected to high temperatures, beakers, flasks and various other scientific glassware, also for fine glassware in the home.

5. **Flint Glass.**—A third variety of glass is made by fusing together silica, potassium carbonate and lead oxide instead of lime. A beautiful clear glass is obtained called *flint,* or in its purest variety *paste,* glass. It is much heavier than either of the other varieties, is very highly refractive, softer and much easier cut. From it are made the various articles of cut glass found on the sideboard, and lenses for all purposes, magnifying glasses, telescopes, eyeglasses, etc. Paste is used for making imitation diamonds. Their brilliancy at

first, while not equal to the diamond, is good, but being so very soft they soon become scratched and lose their value.

6. **Making of Glass Articles.**—Tumblers and similar glass articles are as a rule molded. Bottles are blown by inserting a long hollow tube with a suitable amount of molten glass upon the end into a mold and blowing till the mold is filled. The open end is then finished in a rimming machine. Large plate glass windows are made by pouring the glass upon a table and rolling with heavy iron rollers while the glass is still hot. Later it is ground till perfectly smooth, and polished.

Exercises for Review

1. What is the most abundant natural compound of silicon?
2. Name several varieties of silica. Give colors of them.
3. What are kaolin; felspar; clay?
4. How is water glass made? What is its appearance? Its uses?
5. Why do eggs preserved in water glass crack when boiled?
6. From what is window glass made? What uses are made of crown glass in the laboratory? Why?
7. From what is Bohemian glass made? Give its characteristics?
8. What are its chief uses? Why in the laboratory? Why in the home?
9. From what is flint glass made? What are its chief properties?
10. Would Bohemian glass do as well to make imitation diamonds? Why?
11. What use has flint glass in the home? Why so used?
12. How are tumblers made? Bottles? Plate glass?

CHAPTER XIX

SODIUM FAMILY AND ITS COMPOUNDS

Outline—

1. Names of the Members.
2. Natural Compounds of Sodium.
3. Acid Sodium Carbonate.
    - (a) How Prepared.
    - (b) Uses.
    - (c) Baking Powders—
        - Composition.
        - Kinds.
        - Chemical Action.
        - Comparative Healthfulness.
4. Yeast Bread.
5. Aerated Bread.
6. Sodium Carbonate.
    - (a) Preparation.
    - (b) Uses.
7. Sodium Hydroxide.
    - (a) Preparation.
    - (b) Uses.
    - (c) Soaps.
8. Borax.
9. Potassium Nitrate, Uses.
10. Potassium Carbonate.
    - (a) Sources in Nature.
    - (b) Uses.
    - (c) Suint and Lanolin.
11. Other Potassium Compounds.
    - (a) Potassium Chlorate.
    - (b) Potassium Hydroxide.
    - (c) Potassium Bromide.
    - (d) Potassium Iodide.

Exercises for Review.

1. **Members of the Family.**—There are only two important members of the family, sodium and potassium. There are three others, lithium, rubidium and caesium. They are known as the *alkali metals,* for when added to water, as we have seen in the case of sodium and potassium, they form alkalies. In the chapter on salt we have already studied sodium. Its compounds are of the greatest importance and will be taken up at this time.

2. **Natural Compounds of Sodium.**—Common salt has already been mentioned and its abundance. The only other needing mention is Chile saltpeter, sodium nitrate, used as stated elsewhere for fertilizer and for making gunpowder.

3. **Acid Sodium Carbonate, $NaHCO_3$.**—This is also known as sodium bicarbonate and as cooking soda. It is made from common salt by what is known as the Solvay process which consists of passing a current of ammonia and one of carbon dioxide into a saturated solution of salt. Not being very soluble in water, the acid carbonate separates out in fine crystals. The reactions are given below:

$$NH_3 + H_2O \rightarrow NH_4HO$$
$$NH_4HO + CO_2 \rightarrow NH_4HCO_3$$
$$NH_4HCO_3 + NaCl \rightarrow NaHCO_3 + NH_4Cl$$

The process is very cheap for the ammonium chloride obtained in the third step may be treated with lime and the ammonia recovered for carrying on the process.

Some Uses for Soda.—The more common uses for soda are in the household in cooking. When soda is used for leavening bread, it is brought into contact with sour milk, which contains lactic acid. The soda and acid react setting free carbon dioxide and this held in by the gluten in the flour, expands because of the heat and causes the "biscuit" to rise. The action between the acid and soda is shown by the equation,

$$NaHCO_3 + HC_3H_5O_3 \rightarrow CO_2 + H_2O + NaC_3H_5O_3.$$

From this reaction there is left in the bread sodium lactate, $NaC_3H_5O_3$, which so far as known is harmless. The amount of acid in sour milk varies greatly, however, hence it is difficult to so apportion the soda as to effect exact neutralization. An excess of soda becomes known by brown spots in the bread or by the whole mass being more or less yellow and by the unpleasant alkaline taste. It was this difficulty which led to the adoption so largely of baking powders for soda.

Baking Powders.—All baking powders contain soda. The other active ingredient is some chemical which takes the place of the acid in the sour milk. Often this is an acid salt; sometimes a neutral salt which has the power of decomposing the soda. In all cases carbon dioxide is set free as already described and lightens the bread in the same way. A third substance is necessary as a preservative; this is starch or flour and simply serves to prevent any chemical action taking place before moisture is added in the dough. The starch covers the particles, as has been described elsewhere in keeping salt dry, so that they do not take up moisture from the air and do not come in contact with each other.

Kinds of Baking Powders.—There are numerous brands of baking powders, but probably all may be put under four classes; phosphate powders, cream of tartar powders, alum, and mixed. The phosphate powders contain soda, acid calcium phosphate, starch. The tartrate powders have soda, cream of tartar and starch; the alum powders, soda, aluminum sulphate and starch; the mixed, some variation of the above. What happens in the dough is shown by the following equations:

$$2\,NaHCO_3 + CaH_4(PO_4)_2 \rightarrow 2\,CO_2 + 2H_2O + CaHPO_4 + Na_2HPO_4$$

$$NaHCO_3 + KHC_4H_4O_6 \rightarrow CO_2 + H_2O + KNaC_4H_4O_6$$

$$6\ NaHCO_3 + Al_2(SO_4)_3 \rightarrow 3CO_2 + Al_2(CO_3)_3 + 3Na_2SO_4$$

In the last case a second reaction takes place between the aluminum carbonate produced and the water present, as follows:

$$Al_2(CO_3)_3 + 3H_2O \rightarrow 3CO_2 + Al_2(HO)_6$$

Comparative Healthfulness.—There has been a great controversy for years as to which is the more healthful powder and each manufacturer has made claims for his own against the others. The question depends upon the residue left in the bread. By examining the equations given above it will be seen that the first mentioned leaves two acid phosphates; the second a tartrate, known in medicine as Rochelle Salts; the third leaves two, sodium sulphate and aluminum hydroxide. Which is the least harmful of all these? Mr. Leach, who is perhaps the best authority on the subject in the United States, says that all these residues are recognized in the pharmacopeia as drugs, which in large amounts are harmful in their effects upon the system. But in small amounts, as found in our bread, no experiments have ever been made, as were with the famous "poison squad" in Washington City a few years ago by Dr. Wiley upon various food preservatives. In the absence of such data he does not presume to answer the question. If such authorities can not, it ill behooves people with less experience to do so. The ideal leavening agent, were there not such great difficulties in the way, would be soda and hydrochloric acid. As the equation shows, there would be left as a residue only common salt

$$NaHCO_3 + HCl \rightarrow CO_2 + H_2O + NaCl.$$

The amount of salt thus produced is not as great as that usually added to the bread, hence could not be open to objection.

4. **Yeast Bread.**—In yeast bread no chemical agent is used as a leaven. A microscopic plant called yeast is introduced into the dough and it produces the carbon dioxide through its action on the sugar and starch present. This has already been seen in another chapter. The equation is

$$C_6H_{12}O_6 \rightarrow 2CO_2 + 2C_2H_5OH.$$

The carbon dioxide plays the same part as in all other cases, and on baking, the alcohol escapes on account of its low boiling point. There are objections to this method of making bread and difficulties to be overcome. There is a considerable loss of weight owing to the conversion of the flour into carbon dioxide and alcohol, both of which are volatile. In baking, this loss, including the water also given off, amounts to as much as 15 to 20 per cent. Liebig, the German chemist, some years ago estimated that in the German empire 12,000,000 gallons of alcohol were produced every year in the process of bread making all of which was lost.

It will be seen, therefore, that this is a very wasteful method. Various attempts have been made to save this alcohol, but none of them successful. Further, if the process be continued too long, acid fermentation takes place, and the bread will be sour.

5. **Aerated Bread.**—On account of the loss in making yeast bread efforts have been made to force air into the dough as it is being kneaded. Such bread has a sweet, wholesome taste, but seems inclined to be dry and "chaffy" more like stale yeast bread and has not been received with favor by the public. Its wholesomeness is above question.

6. **Sodium Carbonate, Na_2CO_3.**—Most of the sodium carbonate on the market now is made from the acid carbonate by heating, whereby the hydrogen passes off in the form of water, thus:

$$2NaHCO_3 \rightarrow H_2O + CO_2 + Na_2CO_3.$$

The carbon dioxide expelled is used again in the Solvay process as already described. This gives an anhydrous carbonate, a fine white powder. If the crystalline variety, sal soda, is desired, the anhydrous is dissolved in water and allowed to crystallize, when ten molecules of water are taken up, forming $Na_2CO_3 . 10\ H_2O$. This form is used in scrubbing and for like purposes probably because much more readily soluble in water.

Washing Powders.—Nearly all such powders contain sodium carbonate as the principal ingredient: in addition some of them contain fine pumice stone, small amounts of sodium hydroxide, powdered soap, etc. Pumice is an abrasive and if used on silver or fine articles is apt to scratch them.

Other Uses of Sodium Carbonate.—Sodium carbonate has numerous other uses, one of the more important of which is for the manufacture of common window and other cheap grades of glass; it is used in the manufacture of caustic soda, sodium hydroxide, a very valuable compound, and for softening water. This last is a very important and extensive use. It will be studied later.

7. **Sodium Hydroxide, NaHO.**—Sodium hydroxide is made from sodium carbonate by treating with slaked lime, calcium hydroxide. The equation shows the reaction,

$$Na_2CO_3 + Ca(HO)_2 \rightarrow CaCO_3 + 2NaHO.$$

The calcium carbonate is not soluble in water hence precipitates out and the sodium hydroxide solution is boiled to dryness. The commercial article always contains a considerable percentage of sodium carbonate. It is purified by dissolving in alcohol and evaporating again.

Uses of Sodium Hydroxide.—The chief use is in the manufacture of soap. This is made as described elsewhere by boiling with some fat or oil. For the cheaper grades of laundry soap rosin is used to take the place of a considerable portion of the grease. It makes a yellow soap of a quality inferior to an all-fat soap.

Kinds of Soap.—A very great variety of soap is on the market. Those more or less translucent are what are known as glycerine soaps. From them the glycerine has not been removed; the crude soap has been dissolved in alcohol which separates the opaque portions, the alcohol is evaporated and the soap molded into cakes. Such soaps are expensive because of the added labor in making and for the consumer costly also because being much more soluble in water they do not last long. Floating soaps are made so at least partly by having tiny bubbles of air blown into the pasty mass before cold. They are usually more free from water, hard compressed, and last longer for these reasons.

8. **Borax, $Na_2B_4O_710H_2O$.**—This compound is largely derived from California deposits of calcium borate which is treated with sodium carbonate. Thus:

$$CaB_4O_7 + Na_2CO_3 \rightarrow CaCO_3 + Na_2B_4O_7.$$

The calcium carbonate is filtered out and the borax boiled to point of crystallization. When the borax separates out it takes up ten molecules water of combination as shown in the formula. Borax is a constituent of many washing powders, and in the household is often used to soften water, but is much more expensive for this purpose than sal soda. Mixed with glass it is used in glazing porcelain ware and in enameling: also as a flux in soldering and in small amounts as a preservative in food products.

9. **Potassium Nitrate, KNO_3.**—To a much smaller extent than the corresponding compound of sodium, potassium nitrate is found free in nature. It is a white crystalline salt, used as a preservative for meats, and in making gunpowder. The usual composition of this explosive is

Saltpeter, KNO_3,	75 per cent
Sulphur,	12 " "
Charcoal,	13 " "

In firing it, a detonator, like mercuric cyanate (fulminate) in a percussion cap is used; this starts the decomposition of the nitrate which furnishes free oxygen to burn the carbon and sulphur. Some of the products formed are solids hence the smoke always noticed in exploding this kind of powder.

10. **Potassium Carbonate, K_2CO_3.**—Potassium carbonate, often called pearl ash, is found in wood ashes, in sugar beets, and in the oily deposit called *suint* found on the wool of sheep. The first source is no longer a valuable one, although at one time it furnished a considerable amount of that used in commerce. The sugar beet industry is increasing from year to year and with it the supply of potassium carbonate. In preparing wool for manufacture, it is treated with hot water which removes the grease and potash salt. The oily matter is refined and put on the market for the drug trade under the name of *lanolin* and is used in making various salves and ointments. Potassium carbonate is used mainly for the manufacture of other potassium compounds and for Bohemian glass which is mentioned elsewhere.

11. **Some Other Compounds.**—Potassium chlorate is a white crystalline solid often sold in the form of tablets as a throat medicine. It has a cooling, mild taste, which tends to allay any slight irritation of the throat. Potassium hydroxide, KHO, is used for making soft soap. By saponifying it with linseed oil a special variety of soft soap is made for the drug trade for making salves and various other pharmaceutic preparations. Potassium bromide, KI, is used in tablet form as a sedative in nervous headache, sleeplessness and like troubles. Potassium iodide is also used medicinally.

Exercises for Review

1. Name the members of the sodium family, Which are the important ones?
2. Why are they called alkali metals?

3. Name the two natural compounds of sodium and state where found.

4. What is cooking soda? How made from salt?

5. Explain the action of soda in making biscuits.

6. What do baking powders contain in common? Purpose of it?

7. Name the kinds of baking powders. Give composition of each.

8. What must be known to decide as to the healthfulness of any baking powder?

9. Give the chemical action in a baking powder and compare with soda.

10. Explain the action of yeast. What causes the bread to rise?

11. Why is yeast bread not made from corn meal or flour?

12. Why is ''raising'' bread a wasteful process?

13. What is aerated bread? What can you say of its wholesomeness?

14. How is anhydrous sodium carbonate made? Soda crystals?

15. Give the chief uses of sodium carbonate.

16. What is the chief use of caustic soda? What by-product is furnished?

17. What is a glycerine soap? Why expensive?

18. Where does our borax supply come from? What are some of the uses?

19. Give composition of gunpowder. How is it exploded? Give purpose of each ingredient. Why not smokeless?

20. Give three sources of potassium carbonate. Which is the most important?

21. What is suint? What is lanolin?

22. What is the most important use of potassium carbonate?

23. Name four other potassium compounds with some use of each.

CHAPTER XX

THE CALCIUM FAMILY

Outline—

1. Members of the Family. Another Name for Group.
2. Calcium.
    - (a) Discoverer of.
    - (b) Method of Preparing.
3. Natural Compounds of Calcium.
    - (a) The Carbonate—Interesting Forms.
    - (b) The Sulphate.
4. Artificial Compounds.
    - (a) Lime—Preparation.
        Uses.
    - (b) Precipitated Chalk.
    - (c) Plaster Paris—Preparation.
        Uses.
    - (d) Calcium Chloride.
    - (e) Cements—Kinds.
        Characteristics.
        Uses.
5. Hard Waters.
    - (a) Kinds of.
    - (b) Troubles and Expense of.
    - (c) How Softened—On Large Scale.
        In Household.
6. Strontium and Barium Compounds.
    Use of.
    Composition of Colored Fires.

Exercises for Review.

1. **Members of the Family.**—Belonging to this family there are besides calcium, the most important, barium, strontium and radium. After the sodium group they

are the most strongly positive of the metals. Their oxides as a rule are somewhat soluble in water and produce strong alkalies, from which they are called the "alkaline earth" group.

2. **Calcium, Ca, Atomic Weight, 40.**—Calcium was discovered by Sir Humphrey Davy early in the nineteenth century through electrolysis of the chloride. It is now prepared in the same way and may be had from the larger supply houses. It reacts with cold water though much less violently than does sodium and can be used in the preparation of hydrogen from water.

3. **Natural Compounds of Calcium.**—There are two natural compounds found in abundance, the carbonate and sulphate. The first of these was mentioned when we were studying carbon dioxide. Chalk and all similar natural carbonates of calcium have been produced from the shells of sea animals which had the power of absorbing the small amounts of calcium carbonate from the water and storing it up as a protective covering for themselves. Chalk beds result from a microscopic animal of this kind; limestones from larger ones such as crinoids, and mollusks of all kinds. The well-known Coquina rock, used in making the old fort at St. Augustine, Florida, is composed of pieces of shells, cemented together, so large that even a superficial examination shows the character. Calcium sulphate in nature is known as gypsum: it occurs sometimes beautifully crystallized and in one delicately tinted variety is known as alabastine, used in making vases and other articles of like character.

4. **Artificial Compounds—Lime, CaO.**—Lime is made in kilns by heating at a high temperature limestone rock for several days. During the process carbon dioxide is expelled as shown by the equation,

$$CaCO_3 \text{ (heated)} \rightarrow CaO + CO_2$$

It is a white, amorphous solid, with strong attraction for moisture and also, if moist, for carbon dioxide. Exposed to the air it rapidly crumbles to a powder and forms what is called air-slaked lime, with the composition of $Ca(HO)_2$. Further exposure results in the absorption of carbon dioxide and a reversal of the original process forming again calcium carbonate. These two facts are shown in the two equations,

$$CaO + H_2O \text{ (from the air)} \rightarrow Ca(HO)_2$$
$$Ca(HO)_2 + CO_2 \rightarrow CaCO_3.$$

If water is added to a lump of lime, chemical union begins, the lump swells, much heat is generated and the lime becomes water slaked. Owing to this being an easy way of obtaining a considerable amount of heat without danger of fire balloonists on long trips usually carry some lime and water. Large amounts of lime, however, exposed to water generate sufficient heat to set fire to any combustible materials present. In the flood at Kansas City in 1903 many box cars loaded with lime standing in the yards were about half submerged: all of them caught fire and burned to the water's edge.

Uses of Lime.—In small quantities it is molded into sticks and used in the calcium light mentioned elsewhere. Slaked, it is used in removing the hair from hides, preparatory to tanning; boiled with sulphur, as a spray for fungi on fruit. This has been studied under sulphur. One of the most important uses is in making mortar for masonry work of dwellings. For large buildings it does not possess the tensile strength necessary. In making mortar it is first slaked with water, and sand is added. For the better grade of houses this is "tempered" by the addition of a small amount of cement. When put into the foundation, hardening takes place first through the loss of water and following this by the absorption of carbon dioxide from the air. This has been shown by an equation in section 4 above. This last process, therefore, may go on for years. Another very important use is for softening water as will be explained elsewhere; also with alum to precipitate the mud in city water supplies. In the form of lime water, which is a solution of the hydroxide in water, it is used often as a dilute alkali in medicine; and also as milk of lime, which is limewater with considerable portions of the hydroxide in suspension.

Precipitated Chalk.—This is calcium carbonate made by adding sodium carbonate to a solution of calcium chloride: the precipitate is washed thoroughly and dried. Properly made it is a fine, white powder, devoid of any gritty feeling and often used as an ingredient of tooth powders and tooth pastes.

Plaster of Paris, $CaSO_4.H_2O$.—This well-known compound is prepared from gypsum, as lime is from limestone. As the native rock is heated, a portion of the water of combination, about one-fourth, is expelled leaving a compound with the formula given above. It is a fine white powder, whose most striking property is that of hardening rapidly when mixed with water. This is called "setting;" when it takes place, the plaster of Paris again takes up the water previously expelled on heating and returns to the former hydrated condition.

Uses of Plaster of Paris.—For very white walls it is mixed with lime "putty," slaked lime in the form of a thick paste, and applied as the finishing coat in plastering. For ornamental, raised frescoes, panels, and similar ornamental work about large buildings plaster of Paris is extensively used. It also serves as a filler for much of the paper used and is the principal ingredient of many of the crayons used in the school room, also is very commonly applied in dentistry and surgery for casts.

Calcium Chloride, $CaCl_2$.—Calcium chloride is obtained as a by-product in several manufacturing processes. It has some uses in the chemical laboratory for drying gases, and on account of its being deliquescent has been tried in government experiments in maintaining roadways. In many places roads are maintained by the application of an asphalt oil; this prevents dust, wear by heavy traffic, and erosion by heavy rains. Calcium chloride serves mainly to prevent the formation of dust and hence the loss of material by winds and rapid traffic. It does this by absorbing moisture from the air and thus keeping the roadway slightly damp all the time. In rainy seasons or in climates where there is apt to be heavy rain at any time it is not satisfactory because it is rapidly dissolved and carried away in the water. Another use for it is a brine in refrigeration. Claims are made for it that it attacks the metal pipes and containers less than a solution of common salt more often used. As it can be reduced much lower in temperature than ordinary salt brine without freezing, it is especially adapted to refrigeration where the brine must be transmitted some distances from the ammonia plant. This is often done in large cities.

Cements.—Recent United States bulletins show an output of cement for the year of 1915 at close to 90,000,000 barrels and the output increasing rapidly for the last ten years. This will probably continue under normal conditions for years to come. There are two kinds of cements, *natural* and *portland.* When a rock quarry contains in its various layers *all* the different kinds of rock necessary for the preparation of a cement the product obtained is called a natural cement. Usually, however, some portions must be obtained from one quarry and other portions from another. In such cases the cement is spoken of as artificial or *portland.* As the latter kind may have the necessary ingredients carefully weighed out in such proportions as experience has shown to give the best results, they are usually stronger and are preferred for large structures or for those which must stand great strain, such as sky-scrapers and concrete bridges. Usually the composition of natural cements is such that they harden more slowly hence are not suited for such places as sewers, bridge piers or wherever there is apt to be much water. Concrete is a mixture of cement, sand, and crushed rock in the proportions for ordinary work of one, three and five. These amounts are varied, however, according to the kind of work. Cements harden in two ways. One or two of the constituents being made from carbonate rock take up carbon dioxide from the air as lime does and change back to the original rock. This part of the process is slow, as already described: the remainder of the cement originally was a hydrated silicate which lost a portion of its water when the rock was heated in making the cement. This portion, like plaster of Paris, hardens by taking up again the water of combination. Reinforced concrete is concrete containing iron rods or wire or iron in some form to give added strength in case of sudden shocks or strain.

5. **Hard Waters.**—Any water containing minerals in solution which will form a precipitate when soap is added is called hard. There are two kinds of hardness, *temporary* and *permanent.* Temporary hardness consists usually of the acid carbonate of calcium or iron, while permanent hardness is more often the sulphate of calcium or magnesium. Temporary hardness is called such because it may be removed by boiling the water, while permanent hardness can not be removed thus. Acid salts are usually less stable than normal salts: in this case when the water is boiled the acid carbonate is thus decomposed,

$$CaH_2(CO_3)_2 \rightarrow CaCO_3 + H_2O + CO_2$$

The calcium carbonate is not soluble in water hence it precipitates out. It is this fact which causes much of the trouble arising from temporary hardness. It forms on the inside of the pipes in steam boilers, the hot water coils in our furnaces and elsewhere. A layer of this called "boiler scale" or simply "scale" a quarter inch in thickness causes a loss of half the heating effects. As this accumulates it becomes very difficult to heat the water at all: more than this the iron pipe itself becomes very hot, as the heat is not transmitted to the water, it is rapidly burned away and the pipe bursts. It is one of the great problems for all railroads running through country where the water is hard. Fig. 36 shows sections of two pipes—an actual case—thus nearly filled with scale. Moreover, hardness is a great annoyance and expense in other ways. As long as any exists in the water, soap can not do anything toward cleansing. As stated above when soap solution comes in contact with such salts as produce hardness it forms a curdy precipitate which rises to the top of the water and until all the hardness is removed the soap continues uniting with it rather than forming an emulsion to remove the grease which holds the "dirt." In cities using a hard water for their daily supply the expense is very great. In Glasgow, Scotland, some years ago the soft waters from a lake were substituted for their former supply and in the first year the saving in soap was estimated at $200,000. This is such an item that even a low degree of hardness makes it necessary for steam laundries to use every effort to remove it. Many of them use from 50,000 to 100,000 gallons of water a day. This is received from the city mains into large tanks where it is treated with milk of lime and sodium carbonate solution. Analyses are made of the untreated water daily and these chemicals added in just such proportions as are needed so that there shall be no excess. What happens is shown by the equations:

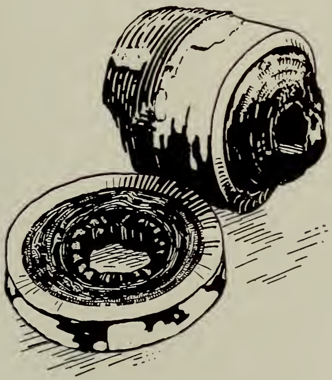


Fig. 36.—Scale in iron pipes.

$$CaH_2(CO_3)_2 + Ca(HO)_2 \rightarrow 2CaCO_3 + 2H_2O$$

In this, the hardness being an acid salt will combine with an alkali, and is thus converted into an insoluble compound and settles out of the water.

$$CaSO_4 + Na_2CO_3 \rightarrow Na_2SO_4 + CaCO_3$$

In this case, the permanent hardness is removed by the calcium salt being converted also into an insoluble compound, the same as in the preceding and settles out with the other. In the home, water if very hard should be treated with a small amount of sodium carbonate before using for laundry purposes, or the bath room. A small amount of ammonia water will do no harm, but is more expensive than the sal soda. Such treatment will be found to effect a great saving of soap at much less cost.

6. **Strontium and Barium Compounds.**—These are not of great importance to us. There are two, however, that are of interest, the nitrates: they are used in making fireworks and colored fires. Strontium imparts a beautiful red and barium a green, and the nitrates, being unstable, are commonly used. For tableaux where electric spot-lights are not available the colored lights are obtained in this way, by making a mixture of powdered shellac, potassium chlorate and strontium nitrate for the red. If green is desired, barium nitrate is substituted for the strontium.

Exercises for Review

1. Name the four members of the calcium family.
2. By what other name are they known?
3. Who discovered calcium? How? How made now?
4. Name the natural compounds of calcium and give some special forms.
5. How is lime made? Give its most important properties.
6. Give several important uses of lime.
7. What is precipitated chalk? What are some of its uses?
8. How is plaster of Paris made? Its chief property?
9. What chemical change takes place when plaster of Paris sets?

10. Give some important uses of it; some uses in surgery.

11. What is the chief property of calcium chloride? Give three uses.

12. What two kinds of cements are there? Explain the difference.

13. What two processes are involved in the setting of cements? Compare with lime and plaster of Paris.

14. What is hard water? Two kinds? How can you know whether a water is hard?

15. What trouble does hardness cause the engineer?

16. What trouble in our homes from hardness? What expense?

17. Show how laundries soften their water. Explain what happens.

18. What is the best way to soften bath or laundry water at home? Why not use lime water?

19. Name one barium and one strontium compound of interest. Why?

20. Give composition of red fire; of green fire. What purpose does each ingredient serve?

CHAPTER XXI

THE MAGNESIUM FAMILY

Outline—

1. Members of the Family and Their Relation.
2. Magnesium.
    - (a) Natural Compounds.
    - (b) Preparation.
    - (c) Properties.
    - (d) Uses.
    - (e) Compounds.
3. Zinc.
    - (a) Historical.
    - (b) Occurrence.
    - (c) Properties.
    - (d) Uses.
    - (e) Compounds.
4. Mercury.
    - (a) History and Old Ideas of.
    - (b) Occurrence of.
    - (c) Characteristics.
    - (d) Uses.
    - (e) Compounds— Calomel.
      Corrosive Sublimate.
      Fulminate and Others.

Exercises for Review.

1. **Members of the Family.**—Belonging to this group of metals are magnesium, zinc, cadmium and mercury. Their atomic weights range from 24 for magnesium to 200 for mercury. Their chemical activities differ about as much. Magnesium is well up in the series and will set free hydrogen from water boiling hot, while mercury will not even do this from acids.

2. **Magnesium.**—*Natural Compounds.*—Some very interesting compounds of magnesium occur in nature; among these are talc or soapstone, asbestos, and meerschaum. Their uses are familiar.

Preparation of Magnesium.—Like most of the metals already studied magnesium is prepared by the electrolysis of some compound, in this case a natural compound of potassium and magnesium chloride. Not a great deal is produced, possibly eighteen or twenty tons a year.

Properties of Magnesium.—As already stated it ranks high in the series of metals in electropositive character, hence displaces hydrogen from dilute acids vigorously. It is steel gray in color, has a specific gravity of 1.75. tarnishes slowly in the air. Heated somewhat it may be drawn into wires and rolled into ribbons in which form it is commonly seen. Cold, it may be ground into a powder and is also frequently seen in this form. It ignites readily in a Bunsen flame and burns rapidly and brilliantly in the air, with a white light, rich in *actinic* rays. By this we mean chemical rays. Sunlight contains not only heat and light rays, but chemical rays as well. It is the last that bring about the changes in a photographic plate and many other things with which we are familiar.

Uses of Magnesium.—To a limited extent it is used in various ways in the chemical laboratory. Its most extensive use is in flashlight photography. Flashlight powders contain magnesium powder mixed with nearly twice the amount of potassium chlorate. Naturally, therefore, they are dangerous and must be handled with care. An alloy of magnesium called *magnalium* consisting of aluminum and magnesium is now being made for use in aeroplanes and elsewhere where a light, tenacious metal is desired.

Compounds of Magnesium.—Magnesium Oxide, MgO.—This is sold under the name of *magnesia.* It is a light, pure white, powder, basic in character, of very high melting point and very poor conductor of heat. It is used extensively for lining crucibles and covering hot water and steam pipes in buildings and conduits. For the latter use it is generally mixed with about 20 per cent of asbestos.

Some Other Compounds.—Magnesium carbonate, prepared in the laboratory, is a mixture of carbonate and hydroxide, thus being a basic salt: $MgCO_3.Mg(HO)_2$. It is a white powder often used in tooth-pastes and as a silver polish. Magnesium chloride has been mentioned already as a very deliquescent compound and the cause of table salt becoming damp in wet weather. Magnesium sulphate, $MgSO_4.7H_2O$, is sold under the name of Epsom salts. Its use in medicine is well known. It is also used in adding weight to cotton goods.

3. **Zinc, Zn, 65.4.**—In order of activity zinc follows magnesium and is next to it in density also. It was not known as a metal to the ancient philosophers, but a natural compound of it was, and it was this fused with copper that gave them their brass and led them to believe in the possibility of transmuting copper into gold.

Occurrence of Zinc.—The greatest zinc-producing region of the United States is what is known as the Joplin District in southwest Missouri. It embraces an extensive area including a portion of southeast Kansas and northeast Oklahoma. The ore found there is in the form of a sulphide, ZnS, called by the miners, "jack." Unlike the metals we have been studying zinc is not reduced electrolytically but by means of carbon. The ore is roasted, which converts it into an oxide as shown in the equation,

$$2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$$

Then the oxide is mixed with crushed coke and heated, whereupon the zinc distills out in the form of a vapor and is condensed.

$$ZnO + C \rightarrow CO + Zn$$

Properties of Zinc.—It is a bluish gray metal, somewhat brittle at ordinary temperatures, malleable between 125° and 150° C., with a melting point of about 420 and boiling point of 950. It tarnishes only slightly in the air and the protective covering thus formed prevents further action of the air. It is not high enough in the electrochemical series to set free hydrogen from water, but it does readily from dilute acids. It is a poor conductor of heat and electricity.

Uses of Zinc.—On account of the last named property it is often used beneath and behind stoves to protect floors and partitions from the heat, also in refrigerators for a lining for the same reason. In most dry cells zinc is the container and serves as the positive *element* while a carbon stick is the negative. Its most extensive use is possibly in what is called galvanized iron. This is iron which has been perfectly cleaned and then dipped into molten zinc. A protective coating of the zinc adheres to the iron. This is used for a very great variety of purposes. Nearly all fencing is now made of galvanized wire; also windmills, stock drinking-troughs, granaries, cornice work, guttering, down spouts, as well as many other things in everyday life. Many alloys of zinc of very great value are also known. An alloy is a mixture of two or more metals: sometimes the resulting product is so different from the metals forming it that it would almost seem as though a chemical change had taken place. Among these alloys of zinc we would mention brass, composed of copper and zinc, and German silver made from copper, zinc and nickel. Some varieties of bronze also contain zinc although usually it has only copper and tin.

Zinc Oxide, ZnO.—This is a product obtained incidentally in many smelters from ores containing a very small percentage of zinc. It is yellow when hot but white when cold. Its most extensive use is as a paint and is sold under the name of *zinc white.* It has some advantages over lead paints in that it is not discolored by hydrogen sulphide gas. It is also used somewhat in the form of an ointment as a remedy for skin diseases and eruptions.

Zinc Sulphate, $ZnSO_4.7H_2O$.—Commercially this is known as *white vitriol.* It may be obtained by treating zinc with dilute sulphuric acid. It is a white compound, readily giving up its water of combination. It is used to some extent as a mordant in dyeing cotton goods. A mordant is a substance which has the power of setting colors in dyeing. Just what the chemical action is is not well understood.

Zinc Chloride, $ZnCl_2$.—Zinc chloride is a white salt, exceedingly deliquescent, prepared by treating zinc with hydrochloric acid. It is used by tinners to obtain a clean surface upon the article to be soldered before dropping the solder. When hot, zinc chloride has the remarkable property of being able to dissolve cellulose; it is by this means that parchment is made.

4. **Mercury, Hg, 200.**—So far as any records go, mercury was first prepared by Theophrastus, 300 B. C., who named it *liquid silver*. It has always since that time been an object of interest and has entered into various theories as to matter, as we have already seen. It is found in nature in the form of a sulphide, called cinnabar, to some extent in California, but most abundantly in Spain.

Characteristics of Mercury.—Mercury is what metallurgists call a *noble* metal, which means that it can be obtained from its ores by heat alone without any reducing agent. It is the only metal liquid at ordinary temperatures, solidifies at –39° C. and boils at 357°. It has a specific gravity of 13.6 so that lead, iron and most of the common metals and alloys float upon it as corks on water. It does not tarnish in the air. One of its most remarkable properties is that of being able to dissolve many of the other metals. Such solutions or mixtures we call *amalgams,* and are really alloys of which one metal is always mercury.

Uses of Mercury.—It is commonly used in thermometers and barometers: in the former because its rate of expansion is high and uniform through a long range, also of high boiling point. In dentistry it is used in making amalgams with silver and tin for filling cavities in teeth. For electric batteries the zinc electrode is often amalgamated to decrease the rapidity of destruction of the zinc; and in a cheap grade of mirrors a tin amalgam is used. One very extensive use is for the recovery of gold in placer and dredge boat mining.

Calomel, Mercurous Chloride, Hg_2Cl_2.—This is a well-known white powder used as a purgative in medicine. Like all mercury compounds it is poisonous, but not being soluble its action is much slower. Except with precautions, salivation is apt to follow its continued use. This is prevented now by the admixture of small quantities of soda with the calomel. The purpose of this is to combine with the hydrochloric acid of the stomach and thus not allow of its reaction with the calomel

$$HCl + NaHCO_3 \rightarrow NaCl + H_2O + CO_2$$

This equation shows that the soda converts the hydrochloric acid into common salt, a very stable body which will not yield its chlorine to the calomel. We have seen heretofore that mercurous chloride is an unsaturated compound; what it probably does, therefore, in the presence of any acid in the stomach, whether that be hydrochloric or acetic from pickles or citric from lemons or grape fruit, is to take up another acid element or group to form a saturated compound. This converts it into a mercuric compound which is much more soluble than the calomel and therefore is taken up by the system rapidly and affects primarily the salivary glands and secondarily the teeth. We can see the reason, therefore, for cautioning patients when taking calomel not to use acid foods.

Mercuric Chloride, Corrosive Sublimate, $HgCl_2$.—This is also a white compound, but crystalline in character. When heated it vaporizes without melting, which is called *sublimation,* hence the name of the compound. It is exceedingly poisonous; the best antidote is probably the white of egg with which it forms a coagulum, not readily soluble. Milk will do, but not nearly so well. It is used as an antiseptic in sterilizing surgical instruments and upon bandages and applications to wounds. It is not poisonous to the body used in this way. Very dilute solutions applied to the scalp occasionally are said to prevent dandruff and constitute one of the ingredients of most hair tonics. Horticulturists also sometimes soak potatoes they are preparing to plant in a very dilute solution of corrosive sublimate for a short time in order to destroy what is known as "scab," a disease making the tuber rough upon the outside.

Mercuric Fulminate, $Hg(ONC)_2$.—This compound has been mentioned in connection with explosives as the detonator needed with most of them for ignition.

Other Compounds.—Vermilion is the artificial sulphide: it is of a brilliant red color, used as a pigment in various cases. Mercuric oxide, HgO, occurs in the red and yellow variety. There is difference only in the size of the particles, the yellow consisting of much the finer. It is the yellow oxide generally used in medicine, for ointments mainly. Its action is probably mainly antiseptic.

Exercises for Review

1. What metals belong to the magnesium family? Which is the lightest? The heaviest? The most active? The least active?
2. Name the natural compounds of magnesium. What are their chief uses?
3. How is magnesium prepared? What is the annual output?
4. Give the chief properties of magnesium. What are actinic rays?
5. What are the chief uses of magnesium? Why are flashlight powders dangerous? What is magnalium?
6. What is magnesia? Chief uses? Give some medical uses.
7. Name three other magnesium compounds. Give their uses. What annoyance does the chloride cause in our homes?
8. What was the earliest use of zinc made by the ancients?

9. Where is zinc found in America? In what form? Called what?

10. How is zinc reduced from its ores differently from other metals already studied?

11. Give chief properties of zinc. Which one of these adds its chief commercial value?

12. Is it safe to make lemonade and allow to stand in a galvanized iron vessel? Why do you say so?

13. What is galvanized iron? How used?

14. Name some alloys of zinc. What is an alloy? What is German silver used for?

15. What is zinc white? Its chief use? What advantage has it?

16. What medical use has zinc oxide? Why so used?

17. What is a mordant? Name one.

18. Give some interesting uses of zinc chloride.

19. When was mercury first made? What are some of the old theories regarding it?

20. What is a noble metal? Give chief properties of mercury.

21. What is an amalgam? Give three uses of amalgams.

22. Why is mercury used in thermometers? Why in barometers?

23. What is calomel? Its use? Its danger? How obviated?

24. What is corrosive sublimate? Why so named? What is its antidote?

25. Give chief uses of corrosive sublimate.

26. What is chief use of mercuric fulminate? What is a detonator?

27. Name two other compounds of mercury. What uses have they?

CHAPTER XXII

THE ALUMINUM FAMILY

Outline—

1. The Aluminum Family.
2. Occurrence of Aluminum in Nature.
    - (a) Relative Abundance.
    - (b) Natural Compounds.
3. Precious Stones.
    - (a) Names and Composition.
    - (b) Synthetic Stones.
4. Other Natural Compounds.
5. Manufacture of Aluminum.
6. Properties of Aluminum.
7. Uses of.
    - (a) As a Metal.
    - (b) In Alloys.
    - (c) Thermit.
8. Alums.
    - (a) Kinds of Alums.
    - (b) Uses of.
9. Aluminum Hydroxide.

Exercises for Review.

1. **Members of the Family.**—In this group aluminum is the only element we shall study. Boron belongs here and we have already studied one compound of it under sodium. The other members of the family are rare and unimportant. Boric acid, H_3BO_3, is a mild antiseptic, and in solution is sometimes used as a medicine for inflamed eyes.

2. **Occurrence of Aluminum.**—Although never found free in nature aluminum is third in abundance of all

the elements, constituting about 8 per cent of the entire amount. It is found in all clays, as well as felspars from which clays are formed, also in mica, used in stoves often under the misnomer of isinglass. Bauxite, a hydrated oxide, fuller's earth, corundum, next to the diamond in hardness, kaolin, emery, and a number of other familiar substances are compounds of aluminum.

3. **Precious Stones.**—The garnet is a calcium aluminum silicate with the formula, $Ca_3Al_2(SiO_4)_3$. The ruby and sapphire are oxides of aluminum colored by minute quantities of other metallic oxides. At the present time they are being manufactured in large quantities by fusing artificially prepared aluminum oxide and coloring them as in nature. The white sapphire is the same compound, uncolored. It is said that between nine and ten million carats of rubies and about half as many sapphires are manufactured annually. They have all the characteristics of the natural stones without the defects, hence are even better. They are often spoken of as synthetic sapphires.

4. **Other Natural Compounds.**—*Emery.*—This is an impure oxide of great hardness, used in the form of wheels, whetstones and other ways as an abrasive. Fuller's earth is a silicate of aluminum used to absorb coloring matter from oils and other articles of commerce.

Kaolin.—Kaolin is a pure, white clay. Mixed with felspar it is used in making porcelain and chinaware. Ordinary pottery ware is made from colored clays, and baked. To glaze the surface salt is thrown into the kiln when it combines with the surface materials forming a silicate and filling the pores.

5. **Preparation of Aluminum for Commerce.**—Like

most of the metals studied up to this time it is obtained by electrolysis, at places where cheap water power may be had for the generation of electric current. Fig. 37 will show the general method. The anode consists of a number of heavy carbon rods while the cathode is the furnace itself. A compound called *cryolite,* meaning *ice stone,* and so called because of its very low melting point, is put into the furnace and melted. Then bauxite, a purified oxide of aluminum, is added. The cryolite dissolves the bauxite as salt would dissolve in water and the heavy current is passed through. The aluminum collects at the bottom and is drawn off at intervals. As the bauxite is used, more is added to take its place so that the process is continuous.

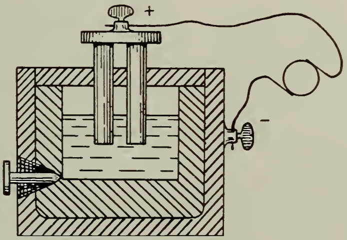


Fig. 37. Manufacture of aluminum.

6. **Properties of Aluminum.**—It is a white metal of low specific gravity, 2.6, being only about one-third as heavy as iron. It is malleable and ductile, but lacking in tensile strength. It is an excellent conductor of heat and electricity, being surpassed only by copper and silver. It does not tarnish appreciably in the air, is below magnesium in electropositive character, yet displaces hydrogen from hydrochloric acid rapidly: with sulphuric very slightly. It is attacked strongly by the alkalies forming compounds called aluminates.

7. **Uses of Aluminum.**—On account of its conductivity it is used extensively for electric cables and feed wires. Although not quite as good as copper, from the fact that the size of the wire determines partly the conductivity and as from a given weight of aluminum a much larger cable can be made than from the same weight of copper, aluminum has advantages even over copper. Perhaps the most extensive use is by steel manufacturers to prevent blowholes in their ingots. Aluminum has the power of combining with the gases formed in the manufacture of steel and thus preventing their remaining in the ingot. If not removed, when these ingots are rolled into steel rails or other objects the gas bubbles make imperfections and weak spots which formerly caused great annoyance. It is being manufactured largely into cooking vessels and is nearly ideal for that purpose. Being an excellent conductor the entire vessel is uniformly heated, while in one of "granite" ware of poor conductivity, the bottom is much hotter. Naturally therefore, foods do not scorch nearly as readily in aluminum vessels. Moreover they are light, do not tarnish readily, are not attacked by the weak acids of food products and are reasonably easy to clean. Ground to a fine powder aluminum is used in oil as a paint for decoration of radiators, as well as many outside objects of metallic character, notably mail boxes, penny weight machines, and the like.

Another very valuable application is in what is known as *thermit.* This is a mixture of ferric oxide and powdered aluminum. It is put into a crucible of suitable size, is primed by a small quantity of powdered magnesium, and lighted. The magnesium in burning generates sufficient heat to cause the more electropositive aluminum to begin combining with the oxygen of the ferric oxide; the action continues and a heat of 3,000° or over is produced. The aluminum oxide formed is melted and rises to the top while the molten iron settles to the bottom and may be drawn off as desired. (See Fig. 38.) The process is a patented one, but is being used extensively in welding all sorts of broken castings, even of the largest character, such as the propeller shafts in large engines and steamships.

Aluminum Alloys.—There are several alloys of aluminum of much value. Magnalium containing a small percentage of magnesium has much greater tenacity than pure aluminum. Aluminum bronze is an alloy of copper and aluminum, the copper not over 10 per cent. It resembles gold more or less closely, is permanent in the air and has many valuable applications, especially in novelty goods. Another aluminum bronze contains a very small percentage of copper and is even whiter than aluminum itself, resembling silver closely. It is even easier to keep bright than silver and is used for some household articles instead of silver.

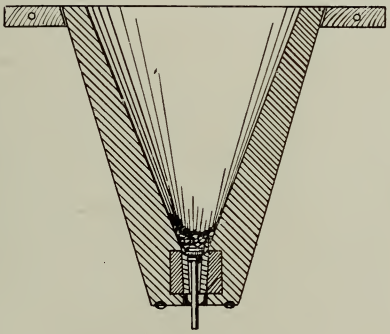


Fig. 38.—Thermit apparatus.

8. **Alums.**—Alums are double sulphates, that is sulphates of two metals, one of which originally was aluminum. But as there are several other elements which may take the place of aluminum in making these double sulphates and give compounds with all the general characteristics, the term alum has come to be applied to all of them. So, any trivalent element, like iron or chromium may be substituted for the aluminum and any univalent element or group, like sodium or ammonium, may be the other part. Common alum is potassium aluminum sulphate, $K_2Al_2(SO_4)_4.24H_2O$. If this is heated to expel the water of combination we have what is called *burnt alum*. It is a mild caustic and is often used medicinally in that way.

Uses of Alum.—As one of the constituents of baking powder alum has already been mentioned. Often however, aluminum sulphate is used instead of alum and is sold to the trade under the name C. T. S. meaning *cream tartar substitute.* Aluminum sulphate is also used as already explained in settling muddy waters for city supplies. We can now understand better what happens by noticing the chemical action as shown by the equation:

$$Al_2(SO_4)_3 + 3Ca(HO)_2 \rightarrow Al_2(HO)_6 + 3CaSO_4$$

The aluminum hydroxide is gelatinous in character and has the power of coagulating and carrying down the sediment. It will be noticed further from the equation that calcium sulphate is added to the water, so that while we are removing the foreign matter we have increased the permanent hardness. This, however, is unavoidable.

Aluminum Hydroxide, $Al_2(HO)_6$.—This is a white solid obtained whenever any alkali is added to a solution of an aluminum salt. It is this that serves as the coagulant spoken of in the preceding section. There are many ways in which aluminum hydroxide is used to some extent. Owing to the fact that it has the power of absorbing foreign matter, if it is precipitated in a solution of a dye it has the power of absorbing the coloring matter and carrying it down with it. Such precipitates are often dried and made into various colored tube-paints called *lakes* used by artists. In the same way paper is often sized that it may be suitable for ink; and dyes are set in fabrics by this method. Aluminum hydroxide is precipitated within the fibers of the cloth and this seizes the coloring matter and holds or fixes it. Fabrics are sometimes waterproofed by dipping in a solution of certain aluminum compounds and then heating by means of steam. The aluminum compound is decomposed with the formation of the hydroxide in the fibers. When dried, being an insoluble compound, it renders the cloth largely waterproof.

Exercises for Review

1. Name two members of the aluminum family. What compound of one have we already studied?
2. What can you say of the abundance of aluminum? Name several natural compounds.
3. Name four precious stones, compounds of aluminum. What is their composition?
4. What is a synthetic ruby? A white sapphire? Why are they better than the natural stones?
5. What is emery? Give its uses.
6. What is kaolin? Its uses? From what is pottery made? How glazed?
7. Describe the method of manufacturing aluminum. What is bauxite? What is the purpose of the cryolite?

8. Give the chief properties of aluminum.

9. What is the most extensive use of aluminum?

10. Why is it used instead of copper for cables? What advantage has aluminum as a cooking vessel?

11. Describe the process of welding by thermit.

12. Name four alloys of aluminum and give uses.

13. What is an alum? What is common alum? What is burnt alum?

14. Give important uses of aluminum sulphate. How does it clarify water?

15. How does aluminum hydroxide serve as a mordant?

16. How are fabrics sometimes waterproofed with aluminum hydroxide?

CHAPTER XXIII

THE COPPER FAMILY

Outline—

1. Members of the Copper Group.
2. Copper Deposits in America.
    - (a) Lake Region.
    - (b) Western States.
3. Characteristics of Copper.
4. Uses of Copper.
5. Copper Sulphate.
    - (a) Source of Commercial Supply.
    - (b) Valuable Uses.
6. Silver, Characteristics.
7. Uses of Silver.
8. Compounds of Silver.
    - (a) Silver Nitrate.
    - (b) Lunar Caustic.
    - (c) Silver Bromide.
    - (d) Silver Chloride.

Exercises for Review.

1. **Members of the Group.**—The copper group consists of copper, silver and gold, all familiar metals and known from remote antiquity. This is because they all are found free in nature and easily worked. Of the three, copper is the most active chemically, then silver and gold. The last is not soluble in any single acid, but in the mixture of hydrochloric and nitric, known as aqua regia.

2. **Copper Deposits.**—The oldest mines in America are those of the Lake Michigan and Lake Superior region. They were known to the prehistoric tribes and the

sheets of pure copper were stripped off from the outcropping layers and beaten into various cups and vessels. These have often been found in the great mounds left by those people. These deposits are still valuable, the mines of Calumet and Hecla being famous. Some are now at a depth of a mile or more and are being worked constantly. Some of the Western States, Montana, Colorado, New Mexico, and Arizona, are also great copper producers, but in those states the metal is in the form of ores and not native copper. With it are usually associated several other metals, gold, silver and sometimes zinc and lead, as well as iron which is not recovered.

3. **Characteristics of Copper.**—Copper is a red metal, very tenacious, malleable, an excellent conductor of heat and electricity, surpassed only by silver. It has a melting point of nearly 1100° C. It tarnishes in the air, ultimately forming, if moisture is present, the basic carbonate, $CuCO_3.Cu(HO)_2$, a greenish compound.

4. **Uses of Copper.**—On account of its excellent conductivity, it is used extensively for electric cables, telephone wires, electric wiring for buildings, etc. A comparison with aluminum in some of these respects has been mentioned elsewhere. Because of heat conductivity it has long been used for cooking vessels wherever acids were not present. Thus in candy factories the kettles are of copper because of the less probability of scorching the sirup, owing to the distribution of the heat over all the surface: stills, evaporating pans and a great variety of similar uses come for the same reason. In the household, copper is not practicable because readily attacked by weak acids like acetic and those found in fruits. In large establishments, like asylums, penitentiaries, and the like, or where quick serv-

ice is essential, such as in the Harvey system of eating houses or other railway restaurants, copper vessels are used but are covered with a thin layer of tin. This protects the copper from the acids and renders the use of the copper vessel perfectly safe. Copper is also used as sheathing for vessels as it is not readily attacked by sea water; for roofing, gutters, down spouts, and the like, being much more permanent than galvanized iron. Its alloys are also very important. Our coins contain copper. Brass is copper and zinc, in varying proportions according to the use to be made of it. Bronze has been mentioned previously; also the alloys with aluminum.

5. **Blue Vitriol, Copper Sulphate, $CuSO_4 . 5H_2O$.**—This familiar compound is often sold under the name of *blue stone.* It is a by-product mainly of some of our great smelters, being obtained in the refining of gold and silver ores. Formerly, the Argentine smelter at Kansas City produced monthly as much as 1,800 tons, with a valuation of nearly $200,000; at the present time the refineries of Omaha and Denver are doing the work formerly done at Kansas City. Blue vitriol is used in one kind of wet battery and is one of the most efficient made. Mention has already been made of its use in preventing the growth of algæ in lakes used as city water supplies. It is employed extensively in making Bordeaux mixture for spraying fruit trees and especially grapes, for the destruction of various fungi. One of the most extensive uses at the present time is for electroplating and electrotyping. The plates from which the pages of books are printed are of copper and what are known as electrotypes. The "lead" type after being proofread is put into page form. An impression of this is taken in a sheet of wax and this covered on

the one side with fine graphite to render it a conductor. This is now suspended in a copper sulphate bath upon the cathode, and a current applied. To keep the solution up to the original strength a sheet of copper is hung upon the anode. The copper is carried to the cathode and deposited upon the graphite giving an exact copy of the lead type. When the thickness has reached about that of a visiting card the sheet is removed from the bath, carefully washed and dried, and molten type metal poured upon the back to give increased thickness and strength. This melts the wax off

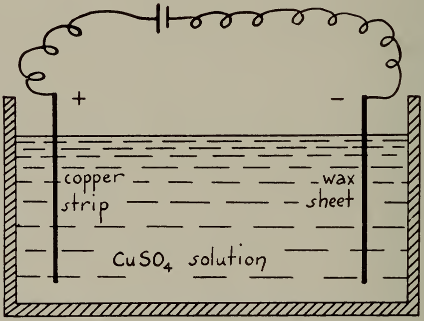


Fig. 39.—Making an electrotype.

and leaves a page of copper type, which from its great toughness may be used in printing hundreds of thousands of copies if desired. Patent advertisements in our newspapers, which make the rounds of the country from city to city, are furnished to the papers in the same way. (See Fig. 39.)

6. **Silver, Ag, 107.88.**—Silver is so well known that little need be said of it in a work of this size. In pure air it does not tarnish, but from the fact that usually there is some hydrogen sulphide present, silverware in our homes does turn dark. This discoloration is silver

sulphide: there are various polishes for removing it, but if the article is not too large to place in an aluminum vessel it may be cleaned most easily in that way. Cover it with water, add a small amount of salt, though even this is not necessary, and boil for two or three minutes. The aluminum being more electropositive, removes the sulphur from the silver and leaves it untarnished. For spoons, knives and other small articles this is a most satisfactory way.

7. **Uses of Silver.**—Little need be said upon this topic as they are so well known. Silver coins of the United States are 900 parts silver to 100 of copper: those of Great Britain are 925 silver to 75 of copper, a little richer than our own. When silverware is spoken of as ''Sterling'' it is not pure silver as many suppose, but of the fineness of English coins, that is, 92.5 per cent and the remainder copper. Silver may be very easily reduced from its compounds; advantage is taken of this fact in depositing it upon glass for all high grade mirrors. They are far superior to the tin amalgam mirrors spoken of elsewhere, which are inclined to blister. It is in this way that the silver deposit is obtained upon the inner surfaces of the vacuum bottle in the thermos bottles now in common use. The student may easily make the experiment by putting a few cubic centimeters of silver nitrate solution into a test tube, adding ammonia water, drop by drop, until the brown precipitate which forms at first has redissolved, then adding a small amount of tartaric acid and heating. The silver will deposit firmly upon the inner surface of the test tube if clean.

8. **Silver Compounds.**—One of the more common is silver nitrate, $AgNO_3$. It is a white, crystalline solid made by dissolving silver in nitric acid. An impure

form, containing a small percentage of silver chloride, is sold in stick form at the drug stores under the name of "lunar caustic." It is a mild cauterant and is frequently used in removing warts from the hands, sometimes for ulcerations of the mouth and throat, as an antiseptic in certain wounds, as dog bites, etc. Most of the hair dyes contain silver nitrate as the active principle, from the fact that when exposed to light, especially in contact with organic matter, it turns dark. Silver nitrate is used in many indelible inks for the same reason.

In photography silver chloride is used mainly on *printing out* papers, such as those the photographer shows in his *proofs*. Silver bromide is generally used both on plates and films and also on the permanent picture. These compounds are prepared from silver nitrate by treatment with potassium or ammonium bromide for the bromide and with common salt for the chloride.

Exercises for Review

1. Name the members of the copper group. Why have they been known so long?
2. State chief facts regarding the oldest mines in America.
3. In what form is copper found in the Western states?
4. Give chief properties of copper.
5. Name the important uses of copper and state why so used.
6. Why is copper not used in most households as a cooking vessel?
7. Brass kettles are sometimes used to make pickles in. Why? What objection?
8. Give two other names for copper sulphate. How is it obtained for commerce?
9. Describe the process of electrotyping.
10. For what is Bordeaux mixture used? Give other uses for blue vitriol,

11. What is the discoloration on silverware? How may it be removed easily?

12. Why do eggs tarnish a silver spoon so badly?

13. What is Sterling silver?

14. How are high grade mirrors made?

15. What is lunar caustic? How different from silver nitrate?

16. Give some medical uses of silver nitrate. Some other uses. What is the chemical reason underlying each use?

17. Name some other compounds of silver and give use.

CHAPTER XXIV

THE LEAD FAMILY

Outline—

1. Members of the Family.
    (a) The Metals.
    (b) Nonmetals Belonging.
2. Deposits of Tin.
    (a) Oldest Deposits.
    (b) Others Now in Use.
3. Characteristics of Tin.
4. Uses of Tin.
5. Compounds of Tin.
6. Lead, Characteristics of.
7. Uses of Lead.
    (a) As an Alloy.
    (b) In Other Forms.
8. Compounds of Lead.
    (a) Lead Acetate.
    (b) White Lead.
    (c) Chrome Yellow.
    (d) The Oxides.

Exercises for Review.

1. **Members of the Group.**—There are only two common metals belonging to this group, tin and lead. Carbon and silicon also belong in the family, but not being metals they are treated elsewhere. Tin is the more active of the two.

2. **Occurrence of Tin.**—It has been known for centuries and was brought from the mines of Cornwall, England, by the ancient Phœnicians. These mines are still productive but more is obtained from the East

Indies and Bolivia. There are no paying deposits at present in the United States.

3. **Characteristics of Tin.**—Its atomic weight is 119. It is a soft metal, white in color, malleable, with a melting point of 232. It is not affected by the air nor by vegetable and fruit acids. Hydrochloric acid is attacked by it setting free hydrogen while strong nitric is rapidly decomposed.

4. **Uses of Tin.**—The most familiar use of tin is for making tin "plate" which is steel covered by a thin layer of tin made by dipping into molten tin, as galvanized iron is in zinc. The use of tin plate now is mainly for "tin" cans, though formerly tin cups, and cooking vessels of all sorts were common. Ordinary solder is an alloy of tin and lead about half and half.

5. **Compounds of Tin.**—Scarcely any of these are of interest to the general student. At least two are used in mordanting and one, stannic acid, is used in weighting silk goods. It is said that most silks are weighted, sometimes very greatly.

6. **Characteristics of Lead, Atomic Weight, 207.1.**—Lead is a dark grayish metal, soft and malleable; is only attacked slightly by the air and this covering serves as a protection, much as a coat of paint. It has a melting point of 325° C. and specific gravity of 11.38. It has very little power of decomposing acids, from the fact that it is next to hydrogen in the scale, hence but little more positive than hydrogen itself. Its salts are all poisonous and form what are known as *accumulative* poisons, that is, the system is unable to eliminate them. Persons working with lead compounds therefore are apt sooner or later to be seriously affected by the poison.

7. **Uses of Lead.**—It is used in sheet form as linings for sulphuric acid chambers in the manufacture of that

acid, for sinks, and in various other places where acids are being used. An extensive use is in the form of pipe for covering underground cables of telephone and telegraph wires, as well as overhead cables: waste pipes in the plumbing of all houses and buildings, and various other ways. As an alloy in solder it has been mentioned, also in type metal.

8. **Compounds.**—*Lead Acetate*, $Pb(C_2H_3O_2)_2.3H_2O$.—This is commonly sold at drug stores under the name of *sugar of lead.* It is a white crystalline salt with an unpleasant, metallic, sweet taste. Like all lead salts, it is very poisonous. It is often recommended for application in cases of "poison ivy."

White Lead, $2PbCO_3.Pb(HO)_2$.—It will be observed that this is a basic salt, being a mixture of the carbonate and a base, lead hydroxide. It is the oldest white paint known and used extensively. One objection is the danger of poisoning to which the laborers in the factory are subjected as well as the painter who applies it. Another objection mentioned elsewhere is that in the presence of hydrogen sulphide it is darkened because of the fact that the lead carbonate is being changed into the sulphide which is black. It is a very durable paint, however, and very satisfactory for most places.

Chrome Yellow, $PbCrO_4$.—Chemically this compound is known as lead chromate. It is the most common yellow pigment.

The Oxides.—There are three oxides of lead. The most common one, lead monoxide, PbO, is a by-product of the silver refineries. It is a yellowish or brownish powder, used extensively for the manufacture of flint glass as mentioned elsewhere. Red lead, Pb_3O_4, is a bright red powder, used with oil in making tight gas-joints in plumbing and in the manufacture of glass.

Exercises for Review

1. What metals belong to the lead family? What two non-metals?
2. Name the three best tin producing regions of the world.
3. Describe tin. Why is it used as a covering for copper cooking vessels?
4. Why is it used in solder? Why in tin plate?
5. Name one compound of tin of interest and give use.
6. Give the chief characteristics of lead.
7. What is a cumulative poison?
8. Give the chief uses of lead. What alloys have we studied?
9. What is sugar of lead? Why so called? Its use in medicine?
10. What is white lead? Its use? Objections to its use?
11. What is chrome yellow? Its use?
12. Name two oxides of lead? What are their uses?

CHAPTER XXV

IRON AND COMPOUNDS

Outline—

1. Distribution of Iron Compounds.
2. Ores of Iron.
    (a) Composition of.
    (b) Field Tests for.
3. Varieties of Iron.
    (a) Composition.
    (b) Comparison of Properties.
4. Varieties of Steel.
    (a) Composition.
    (b) Uses of.
5. Compounds of Iron.
6. Tempering Steel.

Exercises for Review.

1. **Occurrence of Iron.**—Iron is very widely distributed in nature. It is found to a greater or less extent in all soils and clays; nearly all rocks and metallic ores also contain more or less iron associated with them. It is this that more often gives the brownish or red colors observed. Iron is also found in traces in our foods and in the hemoglobin of the blood.

2. **Ores of Iron.**—The most valuable ore of iron in the United States is hematite, Fe_2O_3. A similar compound, limonite, often called brown hematite, with composition $Fe_2O_33H_2O$, is also found abundantly. In some portions of the country magnetic ore, Fe_3O_4, is found in considerable quantities. The last of these shows faint magnetic properties, while the other two give

respectively red, and yellow or brown, streaks upon an unglazed porcelain dish.

3. **Varieties of Iron.**—Iron is the most valuable of all metals from the fact of its numerous uses in modern life. It has three forms, *cast iron, wrought iron* and *steel.* The first is very brittle, of coarse granular structure, containing often as much as 5 per cent of impurity, mostly carbon. Its melting point is much lowered by these impurities. Wrought iron is denser than cast iron, is very tough and malleable, and contains not over 0.2 of one per cent of carbon. Steel varies in amount of carbon from about 0.5 to 1.5 per cent. It has the property when *tempered* of taking an edge needed in cutting tools and is also of very great tensile strength. If wires of the same size, of lead and steel, are tested, the former will sustain without breaking only about one fortieth what the latter will: and even copper will withstand but little more than half what steel will.

4. **Varieties of Steel.**—For various purposes small amounts of other metals are now alloyed with steel, giving certain very desirable properties. Armor plate, a variety very tough, and resistant to sea water, is made of what is known as nickel steel, containing sometimes as much as 4 per cent of nickel. For parts of automobiles, axles and frames, a chrome steel is used, containing small amounts of chromium and vanadium. For burglar-proof safes a manganese steel is used containing 10 or more per cent of manganese. So, other varieties are made to meet the various requirements made of steel.

5. **Compounds of Iron.**—Iron forms a large number of compounds, many of them of great interest to the chemist. Ferric hydroxide, $Fe(HO)_3$, has been mentioned as

the best antidote for arsenic poisoning. Ferrous sulphate, known as *green vitriol,* is often used as a disinfectant. Prussian blue is often used in laundry work to make the articles appear whiter than they would otherwise. It is a complicated salt, known as ferric ferrocyanate with a formula $Fe_4(Fe(CN)_6)_3$. In large laundries, however, coal tar blues have largely taken the place of this iron compound.

6. **Tempering Steel.**—As stated elsewhere iron contains more or less iron carbide. By suddenly cooling it from a high temperature it is found that the amount present is much greater; it is this carbide that permits of the steel taking a cutting edge. After cooling suddenly in this way the steel is too brittle and must be heated again to a much lower temperature and cooled more slowly. By varying this degree of heating different grades of steel are obtained, suited to different kinds of instruments.

Exercises for Review

1. What can you say of the distribution of iron compounds?
2. Name the most valuable ores of iron? Give their composition.
3. Give some easy field test which might be made for each of these ores.
4. Name the three varieties of iron with differences.
5. What uses can you mention for cast iron?
6. Give some uses for wrought iron.
7. Name three varieties of steel and give uses.
8. Give some medical use of ferric hydroxide.
9. How is steel tempered?

CHAPTER XXVI

SOME COMMON POISONS

Outline—

1. Preliminary Statement.
2. Classification of the Poisons.
3. Individual Susceptibility.
4. The Strong Acids.
    - (a) Symptoms.
    - (b) Antidotes and Treatment.
5. The Alkalies.
    - (a) Symptoms.
    - (b) Treatment.
6. Nonmetallic Elements.
    - (a) Effects of.
    - (b) Treatment.
7. Metallic Compounds.
    - (a) Symptoms.
    - (b) Antidotes and Treatment.
8. Vegetable Compounds.
    - (a) Effects and Symptoms.
    - (b) Treatment.
9. Animal Products.
    - (a) Uses and Effects.
10. Neurotics.

Exercises for Review.

1. **Preliminary Statement.**—Most of the poisons which will be mentioned in this chapter have been studied in other places in the book but rather from another viewpoint than their toxic properties, although those have been mentioned. It seems well to have them all put together in case a hasty reference is desired.

2. **Classification of Poisons.**—There seems no way which is satisfactory in every particular for classifying the various poisons. Several different methods have been proposed, all of which are open to some objection. For our brief study we shall take them up as to their general effect upon the body. The following outline will give the plan.

A. Irritants Proper.
    I. Strong Acids.
        1. Sulphuric.
        2. Nitric.
        3. Hydrochloric.
    II. Strong Alkalies.
        1. Caustic Soda.
        2. Caustic Potash.
        3. Ammonia.
B. Specific Irritants.
    I. Nonmetallic Elements.
        1. Phosphorus.
        2. Chlorine.
        3. Bromine.
        4. Iodine.
    II. Metallic Compounds.
        1. Arsenic Compounds.
        2. Antimony Compounds.
        3. Mercury Salts.
        4. Lead Acetate, White Lead, and Others.
        5. Copper Salts.
        6. Zinc Salts.
    III. Vegetable Compounds.
        1. Oxalic Acid.
        2. Phenol.
        3. Croton Oil.
        4. Castor Beans.
    IV. Animal Preparations.
        1. Cantharides.
        2. Ptomaines.

- C. Neurotics.
    - I. Cerebral.
        - 1. Opium and Kindred Drugs.
        - 2. Anesthetics, etc.
    - II. Spinal.
        - 1. Strychnine and Kindred Drugs.
    - III. Cerebrospinal.
        - 1. Belladonna and Kindred Drugs.

3. **Individual Susceptibility.**—The effects of any poison vary greatly with the individual, so that what is a toxic dose for one will not even produce serious effects upon another. It is impossible, therefore, to make any absolute statement as to quantities. For example, the usual medical dose of strychnine is probably about $\frac{1}{60}$ of a grain; yet half that amount has been known to produce serious poisoning, while on the other hand two or three grains have been taken without fatal results. So it is with all poisons.

4. **The Strong Acids.**—

Symptoms.—The three strong acids produce symptoms closely resembling, although the hydrochloric is not so severe in its effects as the sulphuric and nitric. They produce intense burning pain in the mouth, throat, and stomach. Vomiting usually follows, the stomach contents containing, in the case of sulphuric acid, especially, shreds of the mucous lining, blood clots, with the whole brown to black. With nitric acid the vomited portions are yellow to brown. Any spots upon the clothing should be observed. Nitric acid makes a brown stain not removable by any alkali: hydrochloric is a rather bright red turning deeper in color when dry, while sulphuric acid is a deep red, remaining moist and very shortly destroying the fabric entirely with a soft sticky feeling.

Treatment.—The chemical antidote of any acid is an alkali or base. Internally, however, or upon the skin, only the mildest forms can be used. Upon the clothing it is different. Soda is an alkaline salt, readily decomposed by any acid, and an excellent antidote. Likewise, magnesia, a basic oxide, prepared chalk or magnesium carbonate are all good. But in severe cases of any of these acids there is little chance of doing anything more than to alleviate the sufferings somewhat. The stomach pump can not be used as the walls of the esophagus and stomach have been so softened as to be liable to puncture by the slightest pressure.

5. The Alkalies.—

Caustic Soda and **Caustic Potash** are alike in their effects and may be considered together. The mouth and throat as well as stomach are severely burned, resulting in great pain as was the case with the acids. There is a strong, acrid, soapy taste in the mouth and vomited portions are apt to be brown in color, occasionally with some blood.

Treatment of Alkali Poisoning.—The antidote is naturally an acid. The best in such cases are such acids as citric, given in lemonade or by grape fruit, and dilute vinegar, if lemons are not to be had. Vegetable oils which tend to form emulsions and soaps with the alkalies are also helpful, but in severe cases little hope can be held out for anything more than temporary relief. Barley water, very thin gruels and similar soothing liquids are also sometimes helpful. The stomach pump can not be used for reasons mentioned under the acids.

Ammonia.—Poisoning by ammonium hydroxide is rare; when such happens the symptoms are somewhat more violent and in addition to the caustic effects upon the mouth and throat the bronchial tubes and lungs will also be seriously irritated. Most ammonia cases are those of accident caused by the bursting of pipes in refrigerating plants. In such cases the effects are mostly upon bronchi and lungs. Treatment in such cases is most difficult and little can be done for relief.

6. **Nonmetallic Elements.**—

Phosphorus.—As has been seen elsewhere it is the yellow variety of phosphorus that is poisonous. Formerly children were often poisoned by putting match heads into their mouths, but under the present laws this can not occur. Some rat poisons contain the yellow variety and accidents may occur from that source. Chronic cases come in the form of ''phossy jaw'' from working in the factories, but with the safeguards now thrown around the industry from beginning to end these should be very few in the future.

Symptoms.—Phosphorus, being an irritant, produces violent pain in the throat and stomach, as do the acids and alkalies, but usually much slower in appearing. Vomiting usually follows, with considerable thirst. The portions thrown up have the characteristic odor of phosphorus and will glow in the dark. If death does not follow shortly, the nervous system is affected which becomes noticeable in twitchings and great prostration.

Treatment.—There is no satisfactory antidote for phosphorus. Emetics should be given, also some mild cathartic. As phosphorus is soluble in vegetable or animal oils, these should not be given as has been suggested in the case of the alkalies. These oils would simply aid in the absorption of the phosphorus into the system.

Chlorine.—Chlorine, being a gas, attacks the nasal passages, bronchi, and lungs. With any very considerable exposure to it the results are very severe. Inflammation and congestion follow which, except with the greatest care, are very apt to be followed by pneumonia or other similar troubles. All such cases are very difficult of treatment. Ammonia is an antidote for chlorine, but if used it must be very greatly diluted with air. Even then it tends to form an ammonium salt within the air passages which in itself is an irritant. The fumes of alcohol also will sometimes give slight relief.

Bromine.—This is a heavy, red, very volatile liquid. If the fumes are inhaled the results are similar to those of chlorine, probably as serious and as difficult to treat. More often, however, poisoning by bromine is external, in the form of severe burns. Upon the skin it is a powerful irritant and exceedingly rapid in its action. Within a minute the skin is wrinkled as though it had been in hot water for hours; inflammation and excessive burning pain follows. Such wounds should be thoroughly washed, then treated with a very mild alkali, such as a dilute solution of soda or something similar, then after a short time again washed well and a dressing of oil applied. Such wounds are slow in healing.

Iodine.—Although iodine is a commonly used medicine, cases of poisoning by means of it are probably rare. Externally it produces irritation, but not sufficient to call it toxic and no treatment is needed. Internally it is a violent irritant producing symptoms much like the other poisons of this group. Dizziness and faintness are sometimes pronounced. Vomited portions, if starchy foods are present, are apt to be blue, or so very dark in color as to appear black. Dilution of such portions will show the blue color. Iodine, belonging to the acidic elements, would naturally call for an alkaline antidote; hence soda, magnesia, or something similar in small quantities is suggested. Starchy foods are also sometimes given, followed by an emetic.

7. Metallic Compounds.—

Arsenic Trioxide and Other Arsenic Compounds.—Poisoning by means of arsenic compounds is probably by far the most common. It is very difficult to give clear-cut, specific symptoms for arsenic poisoning as they vary so greatly with different individuals. Perhaps the most pronounced is that of severe cramping in the calves of the legs accompanied by acute pain in the stomach region. Usually this latter is greatly increased by pressure. There is usually bad taste in the mouth, more or less salivation, and the common irritation of throat and esophagus.

Tests for Arsenic and Treatment.—The tests for arsenic are varied and not difficult to make, as has been shown elsewhere. Marsh's test requires time for the separation of the arsenic compounds from the food particles hence is more often used in postmortem examinations for legal cases. Reinsch's test is rapid as are several others and requires no special apparatus. As a rule arsenic is not a rapid poison and if suspected, tests can be made upon any portions of the stomach contents thrown up. The antidote has been suggested in the chapter on arsenic, the best being freshly prepared ferric hydroxide. The chemicals needed for preparing this, ammonia water and ferric chloride, are found in every laboratory and pharmacy.

Antimony.—Poisoning by antimony is most apt to be from tartar emetic. The more common symptoms are excessive vomiting, purging, great thirst, with a peculiar metallic taste in the mouth and severe pains in the throat and stomach. Tannic acid is said to be the best antidote, after the use of which the stomach pump should be used and plenty of water.

Mercury.—Poisoning by mercury salts is somewhat common. Salivation from use of calomel is not nearly as frequent as some years ago when precautions now used were not taken. But corrosive sublimate tablets are often mistaken for harmless ones; moreover, there is a widespread idea that death by mercuric chloride poisoning is painless, hence it has frequently been used by suicides in late years. The usual symptoms of severe pain in the stomach follow rapidly upon swallowing the drug; respiration becomes painful and not deep; pulse weak and irregular; great thirst; severe cramping in arms and legs; abdomen becomes swollen and very sensitive to pressure; continued metallic taste in the mouth and if death does not come for some days, the usual effects of mercury upon the salivary glands and teeth.

Treatment for Mercury Poisoning.—The best antidote is the white of eggs. This forms an insoluble compound with the mercury and prevents its absorption by the system. It is said, however, that like many other cases as for example, mercuric iodide in excess of potassium iodide, mercury salts are soluble in excess of albumin; the precaution must be taken, therefore, not to overdo the treatment by giving too much of the white of eggs. One egg is sufficient for four grains of the corrosive sublimate. If eggs are not at hand milk will do but not so well.

Lead Poisoning.—As has been suggested elsewhere, lead poisoning is usually of chronic form, that is, it comes through the gradual accumulation of lead salts in the system. This is more often found with the workmen in the white lead factories or with painters who absorb it through the pores of the skin: often it comes from use of cosmetics and hair tonics. It produces what is known as *painters'* or *lead colic.* It may result, however, from drinking water, which enters through service pipes of lead, very unusual at the present time, or from external applications in case of ivy poisoning or other skin troubles. The symptoms appear very gradually; loss of appetite, general debility, metallic taste persistent in the mouth, indigestion, and unusual thirst. Constipation usually accompanies, with movements very dark when they do occur. Often, perhaps usually, a bluish line appears along the front teeth especially where they meet the gums. Later the muscles of the arm become more or less palsied for which reason the disease is sometimes spoken of as *lead palsy.*

Treatment for Lead Poisoning.—There is no good antidote for lead poisons. It is perhaps most insoluble in the form of a sulphate, hence the giving of some soluble sulphate like magnesium sulphate would be expected. Sodium sulphate might also be used, but the Epsom salt serves as a purgative at the same time rendering the lead insoluble, hence it is the better. However, as the lead is throughout the system and not simply in the digestive tract alone, no antidote can give immediate or even any relief except in small degree. The conditions causing the trouble must be removed and there is then some possibility that the individual may eventually throw off the poison.

Copper Poisoning.—Poisoning by copper salts more often comes through food products. Housewives sometimes prepare their green pickles by adding small amounts of blue vitriol or by heating for a time the vinegar and vegetable to be prepared in a brass kettle. Either method gives a beautiful natural green color to the finished product; until the pure food laws became severe such addition of copper salt was not uncommon in the pickles found in the grocery. Apple butter is sometimes innocently prepared in large brass kettles or boilers with copper bottoms: in either case a considerable amount of copper salt finds its way into the food product. Probably, only with individuals specially susceptible to copper poisoning would the amount contained be sufficient to produce serious results, but they sometimes follow use of such food products. The symptoms are similar to those of lead, but the line at the teeth will be of a greenish color.

Antidote for Copper.—The most insoluble compound of copper obtainable under such circumstances is the ferrocyanate. This may be prepared in the laboratory by adding potassium ferrocyanate solution to a copper salt. If the ferrocyanate is given in dilute solution to the patient, the insoluble compound is obtained; this must be removed by emetics. If this antidote is not accessible, white of eggs or milk will also serve the purpose.

Zinc Salts.—Several zinc compounds are used more or less in medicine. The chloride constitutes the main ingredient of a certain cancer remedy; zinc oxide is used in various skin applications; zinc sulphate is sometimes given as an emetic. As the last closely resembles Epsom salts in its appearance, it has sometimes been taken in that way by mistake. All of the uses suggested permit of accidental poisoning by them. Taken internally, especially in large doses, all zinc compounds are violent irritants and cause intense pain, vomiting and purging. Perhaps as good treatment as can be suggested is the albumin of eggs, or milk, or common soda dissolved in water. All should be followed by emetics or the use of the pump and evacuation of the intestinal tract.

8. **Vegetable Compounds.**—

Oxalic Acid.—Oxalic acid is found in nature in rhubarb and various other plants. It is manufactured from sawdust or sugar by treating them with strong nitric acid. On account of its cheapness and ease of obtaining, it is often used for suicidal purposes. Symptoms of oxalic poisoning are so varied it is difficult to give any description. In concentrated form it causes pronounced twitching of the muscles of the extremities, prostration and heart depression. Later cramps, delirium and even convulsions may follow.

Antidote for Oxalic Acid.—From its nature the antidote would be alkaline in character; hence, magnesia or milk of lime, especially the latter as it would form the oxalate of calcium, the most insoluble of the compounds. Prepared chalk is also good as it gives the same reaction. Soda, usually a good antidote for acids, would not do here for sodium oxalate the product resulting is poisonous and soluble and hence would pass into the system as readily as oxalic acid itself. The usual methods of following by an emetic or use of the stomach pump should be observed.

Phenol.—This compound is perhaps more often sold under the name of *Carbolic Acid,* though, strictly speaking, it is more properly an alcohol, as the ending indicates. It is widely used in medicine both as an antiseptic and deodorant and frequently is the cause of accidental or premeditated death. Applied externally it blisters the skin and turns it white, producing local anesthesia. Internally it causes intense burning pains;

the temperature is lowered, likewise the respiration; pulse weak, but rapid; delirium, convulsions or coma and death.

Treatment for Phenol.—Owing to the muscles of the stomach being more or less completely anesthetized, emetics will not cause the removal of the stomach contents in cases of poisoning by carbolic acid. Sodium sulphate is recommended as the best antidote, given in a cup of water. Milk of lime or soap suds may also be used. In any case the stomach pump should follow.

Croton Oil.—This is perhaps the most powerful purgative used in medical science. It is a violent poison; one of the first symptoms which follow rapidly the taking of the oil is intense pain in the stomach, griping, vomiting and purging. These follow one another at frequent intervals, accompanied by great pain, ending with convulsions, collapse and death. Successful treatment is very difficult. Probably olive oil, followed by soap suds and the stomach pump is as effectual a method as any.

9. **Animal Products.**—

Cantharides.—This is often known as *Spanish Fly.* It is a small beetle found in Spain in abundance, containing an active principle known as cantharidin. Ground cantharides is a brown powder, containing bright green particles, and having a disagreeable odor. It is used in plasters to produce blisters. It is a violent poison and taken internally, causes intense suffering, vomiting and purging, great thirst and difficulty in swallowing. The urinary and genital organs especially are irritated. The only treatment is by an emetic or evacuation of the stomach as speedily as possible.

Ptomaines.—This class of poisons in the outline has been placed under "Animal Products." Ptomaines are really chemical compounds belonging to what are called amines or substituted ammonias. Thus, NH_3 is ammonia; it is possible to remove one or more of the hydrogens and substitute therefor hydrocarbon groups. Thus, the group, CH_3, methyl, may be substituted for one of the hydrogens in ammonia giving the compound, NH_2CH_3, called methyl amine. The ptomaines belong to this class of compounds. They are the result usually of the decomposition of meat or meat products, as all such food products contain nitrogen in addition to the hydrogen and carbon necessary for the formation of the amines. Symptoms vary to such an extent that no general statement can be given. Furthermore no antidote can be offered and each case must be taken on its individual peculiarities.

10. **The Neurotics.**—From the nature of the drugs belonging under this heading and from the stringency of the laws regarding the sale of such drugs it probably would not be of value to discuss them in a work of this size. In the table which will be found on page 276 in the next chapter some of their more general symptoms and method of treatment will be given. This will probably be sufficient for the student's needs.

Exercises for Review

1. Give the three main divisions of the poisons.

2. Into what two classes are the irritants proper divided? Give three examples under each division.

3. What are the more striking symptoms in case of the strong acids?

4. What is the antidote for an acid? Why? What is the chemical action?

5. Are chalk and soda alkalies? Why may they be used as antidotes for acids?

6. What is the natural antidote for an alkali? Why? What particular acid would you suggest?

7. Would hydrochloric acid do as an antidote for caustic soda poisoning? Give reason for your answer.

8. What may be the sources of phosphorus poisoning?

9. Give two methods which would render sure your diagnosis of phosphorus poisoning?

10. What is the recommended treatment for such cases?

11. Why are chlorine and ammonia specially difficult of treatment? What is suggested in each case?

12. Wherein lies the chief danger in chlorine poisoning in case death is not prompt?

13. What cases of bromine poisoning are most apt to be met with? What is the treatment?

14. What is one of the principal things to observe as aid to diagnosis in iodine poisoning?

15. Give two tests for arsenic. Which is the delicate one?

16. What two antidotes are suggested for arsenic? How is the first made?

17. What are the two commoner sources of poisoning by mercury?

18. What are some of the more pronounced symptoms in mercurial poisoning?

19. What is the treatment for bichloride of mercury poisoning? Why is albumin suggested in many cases?

20. What kind of a poison is lead? What disease does it cause? What are some of the symptoms?

21. What is the treatment for lead palsy? Why can it not have immediate or pronounced results?

22. How may copper poisoning come through food products?

23. Why does the housewife sometimes prepare such products in brass kettles?

24. What is the treatment for both zinc and copper poisoning?

25. What is the antidote for oxalic acid? Why not soda as was suggested for other acids?

26. What is phenol? Give its external effects.

27. Why are emetics of little avail in carbolic acid poisoning?

28. What antidotes are suggested for phenol?

29. What is the use of Cantharides? What is its internal effect?

30. What are ptomaines? How produced? What can be said of treatment?

APPENDIX

Table of More Common Poisons—Diagnosis—Antidotes

NAMES	AID IN DIAGNOSIS	SYMPTOMS	ANTIDOTE OR TREATMENT
Sulphuric acid—Oil of Vitriol	On clothing, red spot, remains moist, sticky, hole appears.	Intense pain, vomit black or bloody shreds of mucous lining.	Soda, milk of lime, chalk, barley water. No pump.
Nitric acid Aqua fortis	Brown spots on clothing or skin. Not removed by alkali.	Same as above; vomit yellow or brown.	Same as above.
Hydrochloric Muriatic	Bright red spots on clothing; turn deeper red. Dry.	Same as above; less severe.	Same as above.
Sodium and Potassium Hydroxides	Make skin slippery; woolen cloth likewise.	Severe burning pain; acrid soapy taste.	Lemonade, grape fruit juice, diluted vinegar. No pump.
Ammonia	Odor of breath.	Burning pain bronchi and lungs.	Very dilute chlorine from bleaching powder.
Phosphorus	Odor of breath. Glow in dark of vomit.	Slower violent pain, thirst, nervous symptoms.	Emetics and mild cathartics; no vegetable oils.
Chlorine	Odor of breath.	Catarrhal effects, burning bronchi and lungs.	Very dilute ammonia, alcohol fumes.
Bromine	Shriveled skin, brown stain.	Serious burns on skin, intense pain.	Mild alkalies, soda, limewater, oils.
Iodine	Stain, odor. Vomit blue.	Severe pains, dizziness, faintness.	Mild alkalies, emetics.
Arsenic trioxide, Arsenic	Reinsch's test.	Cramping in calves of legs, pain in abdomen, greater by pressure.	Ferric hydroxide, freshly made, magnesia.

TABLE OF MORE COMMON POISONS—DIAGNOSIS—ANTIDOTES—Cont'd

NAMES	AID IN DIAGNOSIS	SYMPTOMS	ANTIDOTE OR TREATMENT
Antimony tartrate; tartar emetic		Metallic taste, purging, vomiting excessive.	Tannic acid, pump, water.
Mercury bichloride, Corrosive sublimate	Reinsch's test. See text.	Breathing shallow, weak, painful, pulse weak, cramps in arms and legs.	Egg albumin, milk.
Lead salts	Blue line on gums, general debility.	Metallic taste persistent, no appetite, indigestion, constipation, palsy in arms.	Magnesium sulphate. Recovery slow.
Copper salts	Green line on gums.	Much like lead.	Potassium ferrocyanate; egg albumin, milk.
Zinc salts		Violent pain, purging.	Egg albumin, milk.
Oxalic acid		Twitching of muscles, prostration, cramping.	Chalk, milk of lime, pump.
Phenol, Carbolic acid	Blistered skin.	Intense burning pain, lowered temperature, weak pulse, rapid.	Sodium sulphate, milk of lime, soap suds, pump. No emetics.
Croton oil		Violent purging, frequent, griping pains.	Olive oil, soap suds.
Cantharides	Green wing portions.	Violent vomiting, purging, urinary organs inflamed.	Emetic.
Morphine and Opium		Narcotic. Drowsiness, stupor, coma. Breathing slow, stertorous.	Strong coffee, atropine, stomach washed by pump. Keep awake if possible.
Chloral, Chloral hydrate		Sleep quiet; in large doses, pulse weak, sleep heavy, coma.	Keep body warm; artificial respiration, heart stimulants.

TABLE OF MORE COMMON POISONS—DIAGNOSIS—ANTIDOTES—Cont'd

NAMES	AID IN DIAGNOSIS	SYMPTOMS	ANTIDOTE OR TREATMENT
Strychnine, Nux vomica, Brucine		Restlessness, twitching, difficulty in breathing, tetanic convulsions, face ghastly.	Strong tea, tannin, followed by pump; potassium bromide, chloroform to prevent convulsions.
Belladonna, Atropine		Dryness of mouth and throat, nausea, dizziness, poor vision, pulse rapid, face flushed.	Tannic acid, evacuation by pump, cathartics.
Cocaine		Nervousness, fullness of head, nausea, poor vision, rapid, feeble pulse, breathing shallow.	
Prussic acid Hydrocyanic acid		Breathing difficult, pulse slow, paralysis, death.	Action too rapid in toxic doses for treatment.

The Periodic Law

The student may have wondered in some cases why certain elements have been grouped as they have been in a particular family, when there is marked difference in the characteristics. In the case of the chlorine family, or the sodium family, so far as we have seen there is a marked resemblance among them all; but in other cases as in the carbon family, there is not much similarity in many respects.

As long ago as the middle of the preceding century a number of chemists held a belief that all the elements bore some multiple relation to hydrogen; moreover, they had observed that elements similar in properties were separated from each other in atomic weight by certain definite amount. But it was not until about 1870 that Mendeleeff, a noted Russian chemist, greatly extended these conceptions and perfected them. He observed that on arranging the elements in accordance with their atomic weights, those with similar properties seemed to recur at regular intervals. Thus, Li, Gl, B, C, N, O, F, Na, Mg, Al, Si, P, S, Cl, K, Ca, Sc, Ti, etc., are arranged in accordance with their increasing atomic weights. Beginning with lithium the first element which is like it in properties is sodium, the eighth one; and the next after that which is like these two is potassium, another octave beyond. If we take fluorine, and count on from that we come to chlorine, with similar properties, the eighth beyond. Allowing for undiscovered elements at the time Mendeleeff was working upon this arrangement he came to the conclusion that the elements may be arranged in families depending solely upon their atomic weights. In other words he concluded that the properties of an element depend in some way upon the atomic weight of that element. This idea has now been accepted by chemists as a whole, and the elements have been arranged in a table known as the Periodic Table.

There are a great many very interesting facts which may be observed regarding the elements in connection with this table, but it is not the purpose to bring them out here. By a hasty inspection it will be seen that the families as we have studied them are found in the table in vertical groups.

PERIODIC TABLE

VALENCE = 0 NO COMPOUNDS	VALENCE = 1	VALENCE = 2	VALENCE = 3	VALENCE = 4	VALENCE = 5 IF SATURATED	VALENCE = 6 IF SATURATED	VALENCE = 7 IF SATURATED
He,4 Ne,20	Li,7 Na,23	Gl,9 Mg,24.3	B,11 Al,27	C,12 Si,28	N,14 P,31	O,16 S,32	F,19 Cl,35.5
A,39.9	K,39 Cu,63.6	Ca,40 Zn,65.4	Sc,44 Ga,70	Ti,48 Ge, 72.5	V,51 As,75	Cr,52 Se,79.2	Mn,55 Br,80
Kr,83	Rb,85.4 Ag,108	Sr,87.6 Cd,112.4	Y,89 In,115	Zr,90.6 Sn,119	Cb,93.5 Sb,120	Mo,96 Te,127.5	...... I,127
Xe,130	Cs,133 Au,197	Ba,137.4 Hg,200.6	La,139 Tl,204	Ce,140 Pb,207	Ta,181.5 Bi,208	W,184	....
Nt,222.5	......	Ra,226.5	......	Th,232.5	......	U,238.5	......

In addition to the elements shown in the table there are three groups which do not seem to "fit" anywhere. Thus following manganese, are iron, nickel, cobalt, with weights of 56, 58.7 and 59 respectively; following the blank space below manganese, ruthenium, 102, rhodium, Rh, 103, and palladium, 107; following the blank after tungsten, W, are osmium, 191, iridium, 193, platinum 195.

Solubilities of Common Compounds

It may be desirable to know at times whether a compound is soluble in water. A few general rules may be helpful and are given below.

(a) All salts of the sodium group, including those of ammonium, are soluble, with the exception of two or three very uncommon ones.

(b) All bromides are soluble except those of lead, mercury, and silver.

(c) All carbonates of the sodium group, including ammonium, are soluble; all others are insoluble.

(d) All chlorates are soluble.

(e) All chlorides are soluble except lead chloride, mercurous chloride, and silver chloride.

(f) The hydroxides of the sodium group, ammonium, and the calcium group are soluble, calcium only moderately so, while all others are insoluble.

(g) All nitrates are soluble.

(h) The oxides of the sodium and calcium group are chemically soluble in water, that is, they react to form a new compound, the hydroxide. All other oxides are insoluble in water.

(i) Phosphates are insoluble except those of the alkali metals and ammonium.

(j) Silicates are insoluble except those of the alkalies and ammonium. Even then if mixed with silicates of heavier metals they are insoluble.

(k) The sulphates of barium, calcium, lead, and strontium are insoluble; others are soluble.

Some Interesting Temperatures

Absolute zero	–273° C.
Hydrogen melts	–260
Hydrogen boils	–252.6
Nitrogen melts	–214
Nitrogen boils	–194
Oxygen boils	–182.5
Alcohol freezes	–130
Mercury freezes	– 39.5
Water freezes	0
Room temperature	21
Ether boils	34.6
Human body	37
Wood's Metal melts	60
Alcohol boils	78.5
Water boils	100
Sulphur melts (rhomb)	114.5
Tin melts	232
Lead melts	327
Murcury boils	357
Zinc melts	419
Dull red heat	650
Aluminum melts	660
Bright red heat	1,000
Gold melts	1,064
White heat	1,350
Iron melts	1,520
Platinum melts	1,750
Corundum melts	2,000 (about)
Oxyhydrogen flame	2,500
Oxyacetylene flame	2,700
Tungsten melts	3,000
Thermit gives	3,500 (about)
Electric arc	4,000 (about)

Tables of Weights and Measures

WEIGHTS

10 milligrams (mg.) = 1 centigram (cg.)
10 centigrams = 1 decigram (dg.)
10 decigrams = 1 gram (g.)
1,000 grams = 1 kilogram (kg.)

ENGLISH EQUIVALENTS

1 kilogram = 2.2046 pounds
28.35 grams = 1 ounce
1 gram = 15.43 grains
500 grams = 1.1023 pounds

The unit of weight in the Metric System is the gram.

VOLUMES

1,000 cubic centimeters (c.c.) = 1 liter
1 cubic decimeter (c.d.) = 1 liter
1 liter (l.) = 1.056 liquid quarts

The unit in the Metric System is the liter.

LENGTH

10 millimeters (mm.) = 1 centimeter (cm.)
10 centimeters = 1 decimeter (dm.)
10 decimeters = 1 meter (m.)

ENGLISH EQUIVALENTS

1 centimeter = 0.3937 inches
2.54 centimeters = 1.0 inch
1 meter = 39.37 inches

THERMOMETER EQUIVALENTS

For scientific work the centigrade thermometer is always used and readings given in scientific books are always centigrade unless otherwise specified. Freezing water is 0° C. and boiling point is 100° C.

0 Centigrade is 32 Fahrenheit and 273 Absolute
100 " " 212 " " 373 "

One degree Centigrade = 9/5 of a degree Fahrenheit
One degree Fahrenheit = 5/9 of a degree Centigrade
One degree Centigrade = One degree Absolute

To convert centigrade degrees into Fahrenheit, multiply by 9/5 and add 32, algebraically. This means that if the centigrade reading is below zero, it would have the minus sign and one would be subtracted from the other. To convert Fahrenheit readings into centigrade multiply by 5/9 after subtracting 32 from the Fahrenheit reading.

List of Elements, Their Symbols and Atomic Weights. (O=16.)
(The more important elements are printed in heavy type.)

NAME OF ELEMENT	SYMBOL	ATOMIC WEIGHT	NAME OF ELEMENT	SYMBOL	ATOMIC WEIGHT
Aluminum	Al	27.1	Molybdenum	Mo	96.0
Antimony	Sb	120.2	Neodymium	Nd	144.3
Argon	A	39.88	Neon	Ne	20.2
Arsenic	As	74.96	**Nickel**	Ni	58.68
Barium	Ba	137.37	Niton	Nt	222.4
Bismuth	Bi	208.0	**Nitrogen**	N	14.01
Boron	B	11.0	Osmium	Os	190.9
Bromine	Br	79.92	**Oxygen**	O	16.00
Cadmium	Cd	112.4	Palladium	Pd	106.7
Caesium	Cs	132.81	**Phosphorus**	P	31.04
Calcium	Ca	40.07	**Platinum**	Pt	195.2
Carbon	C	12.00	**Potassium**	K	39.1
Cerium	Ce	140.25	Praseodymium	Pr	140.6
Chlorine	Cl	35.46	**Radium**	Ra	226.4
Chromium	Cr	52.0	Rhodium	Rh	102.9
Cobalt	Co	58.97	Rubidium	Rb	85.45
Columbium	Cb	93.5	Ruthenium	Ru	101.7
Copper	Cu	63.57	Samarium	Sa	150.4
Dysprosium	Dy	162.5	Scandium	Ss	44.1
Erbium	Er	167.7	Selenium	Se	79.2
Europium	Eu	152.0	**Silicon**	Si	28.3
Fluorine	F	19.0	**Silver**	Ag	107.88
Gadolinium	Gd	157.3	**Sodium**	Na	23.00
Gallium	Ga	69.9	**Strontium**	Sr	87.63
Germanium	Ge	72.5	**Sulphur**	S	32.07
Glucinum	Gl	9.1	Tantalum	Ta	181.5
Gold	Au	197.2	Tellurium	Te	127.5
Helium	He	3.99	Terbium	Tb	159.2
Holmium	Ho	163.5	Thallium	Tl	204.0
Hydrogen	H	1.008	Thorium	Th	232.4
Indium	In	114.8	Thulium	Tm	168.5
Iodine	I	126.92	**Tin**	Sn	119.0
Iridium	Ir	193.1	Titanium	Ti	48.1
Iron	Fe	55.84	**Tungsten**	W	184.0
Krypton	Kr	82.92	Uranium	U	238.5
Lanthanum	La	139.0	Vanadium	V	51.0
Lead	Pb	207.1	Xenon	Xe	130.2
Lithium	Li	6.94	Ytterbium	Yb	172.0
Lutecium	Lu	174.0	Yttrium	Yt	89.0
Magnesium	Mg	24.32	**Zinc**	Zn	65.37
Manganese	Mn	54.93	Zirconium	Zr	90.6
Mercury	Hg	200.6			

Names and Formulas of the More Common Chemicals

Acetic acid	$HC_2H_3O_2$
Alcohol	C_2H_5OH
Alum, ammonium	$(NH_4)_2Al_2(SO_4)_4$
Alum, potassium	$K_2Al_2(SO_4)_4$
Aluminum oxide	Al_2O_3
Aluminum sulphate	$Al_2(SO_4)_3$
Ammonium bicarbonate	NH_4HCO_3
“ carbonate	$(NH_4)_2CO_3$
“ chloride	NH_4Cl
“ hydroxide	NH_4OH
“ nitrate	NH_4NO_3
“ sulphate	$(NH_4)_2SO_4$
Antimony oxychloride	$SbOCl$
“ trichloride	$SbCl_3$
“ trisulphide	Sb_2S_3
Arsenic trioxide	As_2O_3
Barium carbonate	$BaCO_3$
“ chloride	$BaCl_2$
“ dioxide	BaO_2
“ hydroxide	$Ba(OH)_2$
“ nitrate	$Ba(NO_3)_2$
“ oxide	BaO
“ sulphate	$BaSO_4$
Bismuth chloride	$BiCl_3$
“ nitrate	$Bi(NO_3)_3$
“ subnitrate	$BiONO_3$
“ trioxide	Bi_2O_3
Bleaching powder	$CaCl(OCl)$
Borax	$Na_2B_4O_7$
Calcium carbide	CaC_2
“ carbonate	$CaCO_3$
“ chloride	$CaCl_2$
“ fluoride	CaF_2
“ hydroxide	$Ca(OH)_2$
“ oxide (lime)	CaO
“ phosphate	$Ca_3(PO_4)_2$
“ sulphate	$CaSO_4$
Carbolic acid	C_6H_5OH
Carbon disulphide	CS_2

Chloroform	$CHCl_3$
Chrome yellow	$PbCrO_4$
Cinnabar	HgS
Copper acetate	$Cu(C_2H_3O_2)_2$
“ chloride	$CuCl_2$
“ nitrate	$Cu(NO_3)_2$
“ oxide	CuO
“ sulphate	$CuSO_4$
“ sulphide	CuS
Ether, sulphuric	$(C_2H_5)_2O$
Ferric chloride	Fe_2Cl_6
“ hydroxide	$Fe_2(OH)_6$
“ nitrate	$Fe_2(NO_3)_6$
“ oxide	Fe_2O_3
Ferrous sulphate	$FeSO_4$
Ferrous sulphide	FeS
Fluor spar	CaF_2
Gold trichloride	$AuCl_3$
Hydrochloric acid	HCl
Hydrofluoric acid	HF
Hydrogen peroxide	H_2O_2
Hydrogen sulphide	H_2S
Hypochlorous acid	$HClO$
Iodic acid	HIO_3
Iodoform	CHI_3
Lead acetate	$Pb(C_2H_3O_2)_2$
“ carbonate	$PbCO_3$
“ chloride	$PbCl_2$
“ chromate	$PbCrO_4$
“ nitrate	$Pb(NO_3)_2$
“ oxide (litharge)	PbO
“ sulphate	$PbSO_4$
Lime	CaO
Litharge	PbO
Lithium chloride	$LiCl$
Magnesia	MgO
Magnesium carbonate	$MgCO_3$
“ chloride	$MgCl_2$
“ oxide	MgO
“ sulphate	$MgSO_4$
Manganese dioxide	MnO_2

Mercuric chloride	$HgCl_2$
“ iodide	HgI_2
“ nitrate	$Hg(NO_3)_2$
“ oxide	HgO
“ sulphide	HgS
Mercurous chloride	Hg_2Cl_2
“ iodide	Hg_2I_2
“ nitrate	$Hg_2(NO_3)_2$
Minium	Pb_3O_4
Phosphine	PH_3
Phosphorus pentoxide	P_2O_5
Plaster of Paris	$CaSO_4, H_2O$
Platinum tetrachloride	$PtCl_4$
Potassium acetate	$KC_2H_3O_2$
“ bicarbonate	$KHCO_3$
“ bromide	KBr
“ carbonate	K_2CO_3
“ chlorate	$KClO_3$
“ chloride	KCl
“ chromate	K_2CrO_4
“ cyanide	KCy
“ dichromate	$K_2Cr_2O_7$
“ ferricyanide	$K_3Fe(CN)_6$
“ ferrocyanide	$K_4Fe(CN)_6$
“ hydroxide	KOH
“ iodide	KI
“ nitrate	KNO_3
“ nitrite	KNO_2
“ permanganate	$KMnO_4$
“ sulphate	K_2SO_4
“ sulphocyanate	$KSCN$
Silica	SiO_2
Silver bromide	$AgBr$
“ chloride	$AgCl$
“ iodide	AgI
“ nitrate	$AgNO_3$
Sodium acetate	$NaC_2H_3O_2$
“ arseniate	Na_3AsO_4
“ arsenite	Na_3AsO_3
“ bicarbonate	$NaHCO_3$
“ carbonate	Na_2CO_3

Sodium chloride	$NaCl$
‘‘ hydroxide	$NaOH$
‘‘ iodide	NaI
‘‘ nitrate	$NaNO_3$
‘‘ nitrite	$NaNO_2$
‘‘ phosphate	Na_3PO_4
‘‘ sulphate	Na_2SO_4
‘‘ sulphide	Na_2S
‘‘ sulphite	Na_2SO_3
‘‘ thiosulphate	$Na_2S_2O_3$
Stannic chloride	$SnCl_4$
‘‘ oxide	SnO_2
Stannous chloride	$SnCl_2$
Strontium nitrate	$Sr(NO_3)_2$
Sulphur dioxide	SO_2
Sulphuric acid	H_2SO_4
Sulphurous acid	H_2SO_3
Sulphur trioxide	SO_3
Zinc chloride	$ZnCl_2$
‘‘ oxide	ZnO
‘‘ sulphate	$ZnSO_4$

GLOSSARY

Chemical Terms

Actinic. Actinic light rays are those which have the power of producing chemical change in substances, as upon a photographic plate.

Alkali. A soluble hydroxide, with caustic properties, sharp biting taste, and power of corroding the skin.

Allotropic. Literally, another form of an element; more often applied to the unusual form. Ozone as related to oxygen.

Alloy. A mixture of two or more metals, melted together so as to be homogeneous. Example, brass.

Amalgam. An alloy, one component of which is mercury.

Amorphous. Without special form; uncrystallized.

Anesthetic. A substance used to produce unconsciousness.

Anhydride. An acidic oxide. An oxide forming an acid on the addition of water.

Anhydrous. Without water.

Antiseptic. An antiseptic is a substance used to prevent decay or destroy pathogenic bacteria.

Basic. Having the properties of a base or alkali.

Binary. A compound consisting of two elements.

Calcine. To heat strongly.

Commercial. A term applied to chemicals not pure but sufficiently so for all ordinary uses.

C. P. Chemically pure. Applied to a better grade of chemicals than those marked "commercial."

Decant. To pour off a liquid from a precipitate.

Deliquesce. To gather moisture from the air and become liquid.

Desiccator. A vessel used for drying substances.

Destructive Distillation. Heating a substance in a closed retort so as to decompose it and produce new substances; as in distilling coal.

Downward Displacement. Collecting a gas heavier than air by letting it flow *downward* into a bottle full of air, thus *displacing* the air.

Distillate. The liquid obtained by distillation.

Dyad. An element with valence of two.

Effloresce. To give up water of combination at room temperature and become a powder.

Electrode. The terminal of a battery.

Empirical. Applied to a formula which shows composition only. Not structural.

Escharotic. A caustic. A substance which corrodes.

Filtrate. The liquid which passes through a filter.

Flocculent. Flaky; often applied to certain precipitates.

Flux. A substance used to lower the melting point of some substance: often it is a solvent for the substance.

Fractional Distillation. Boiling a liquid and separating it into portions or *fractions* by means of their difference in boiling points.

Gelatinous. Jelly-like or starch-like paste; applied to precipitates.

Germicide. A substance destructive of germs.

Gravimetric. Applied to determining the proportion by *weight,*

Halogens. Literally, salt producers: the chlorine family.

Hydrated. Containing water.

Hydroxyl. The group HO, found in all hydroxides.

Hygroscopic. Having the property of becoming moist in damp air.

Indicator. A substance, like litmus paper, used to determine when a reaction has been completed.

Ion. An electrically charged atom or group of atoms. They may be either positive, called *cations;* or negative, called *anions.*

Isomeric. Two compounds are *isomeric* when they have the same percentage composition, the same empirical formula, but are entirely different in properties.

Monad. An element with a valence of one.

Monobasic. Applied to an acid having only one displaceable atom of hydrogen in a molecule, as hydrochloric acid.

Mordant. Something used to set the color or dye in cloth.

Nascent. Literally, *being set free;* applied to a gas as it is being set free from some compound: in the atomic form and very active, chemically.

Neutral. Neither acid nor alkaline in character.

Neutralization. The process of combining an acid and a base so as to exactly destroy the properties of each and form a new compound.

Nitrogenous. Containing nitrogen.

Occlude. To condense within the pores of a metal; as hydrogen in platinum or carbon monoxide in hot cast iron.

Oxidation. The combining of a substance with oxygen. In a broader sense, raising the valence of an element.

Oxidizing Agent. A substance which will bring about oxidation. Usually a substance containing oxygen, with which it will part readily. Often chlorine or bromine.

Paste. A very pure form of flint glass used in making imitation diamonds.

Pneumatic. Term applied to the trough used in collecting gases.

Polymer. A term applied to one compound the multiple of another. Thus, C_6H_6 is a polymer of C_2H_2.

Precipitate. A solid thrown out in a solution; it may be a mere cloud or so very dense and heavy as to settle very rapidly.

Radical. A group of atoms which act chemically as if a single element.

Reaction. The chemical change taking place between two or more substances.

Reagent. A substance used in a chemical reaction.

Roast. To heat strongly in presence of air; hence to oxidize.

Saturated. Fully satisfied. Containing all possible.

Slag. A nearly black glass formed in blast furnaces in the reduction of iron and other metals.

Sublimate. The substance obtained by sublimation.

Sublimation. The process of vaporizing a solid which boils without melting, and collecting the vapors.

Supernatant. Overlying. Said of a liquid above a precipitate which has settled.

Ternary. Composed of three elements or more.

Upward Displacement. Method of collecting light gases by letting them flow *upward* into a bottle of air, *displacing* the air.

Volatile. A term applied to substances which readily change into gas.

Volumetric. Estimation of quantity by measuring the volume, not weight.

Common or Commercial Names

Agate. A species of quartz, often beautifully colored in concentric rings.

Alabaster. A beautiful white or delicately tinted form of gypsum.

Alum. A double sulphate, containing a univalent and a trivalent metal. Common alum is potassium aluminum sulphate.

Alumina. Aluminum oxide.

Amethyst. A variety of quartz, pale violet in color.

Antichlor. A substance employed to neutralize the chlorine used in bleaching. It is generally sodium thiosulphate.

Arsenic. The usual commercial name for arsenic trioxide.

Arsenous Acid. A term often applied to arsenic trioxide. Strictly speaking arsenous acid is H_3AsO_3.

Arsine. Hydrogen arsenide also called arseniuretted hydrogen, H_3As.

Baryta. Barium oxide, BaO.

Baryta Water. Barium hydroxide, $Ba(HO)_2$.

Bauxite. Hydrated aluminum oxide, $Al_2O_3 \cdot H_2O$.

Benzene. More properly called benzol, C_6H_6, obtained from coal tar.

Benzine. A light oil resembling ordinary gasoline, obtained from petroleum.

Bicarbonate of Soda. Cooking soda, $NaHCO_3$.

Bituminous. Containing bitumen or oil.

Blanc de fard. Bismuth oxynitrate, $BiONO_3$.

Blue Vitriol. Copper sulphate crystals.

Borax. Sodium tetraborate.

Butter of Antimony. Antimony chloride, so called from its yellow color.

Calcite. Crystallized calcium carbonate, being three in scale of hardness.

Calomel. Mercurous chloride, Hg_2Cl_2.

Carborundum. Silicon carbide, SiC, used as an abrasive.

Caustic Potash. Potassium hydroxide.

Caustic Soda. Sodium hydroxide.

Chalcedony. A variety of quartz.

Chalk. A soft, natural form of calcium carbonate.

Chloride of Lime. Commercial name for bleaching powder.

Chrome Alum. A double sulphate of potassium and chromium.

Chrome Yellow. Lead chromate, $PbCrO_4$.

Copperas. Ferrous sulphate, green vitriol.

Corrosive Sublimate. Mercuric chloride, $HgCl_2$.

Corundum. Native, uncrystallized aluminum oxide, nine in scale of hardness.

Emerald. Aluminum oxide, crystallized, green in color.

Emery. An impure, native form of aluminum oxide.

Epsom Salts. Crystallized magnesium sulphate.

Felspar. A complicated silicate rock, which, decomposed, forms clay.

Fool's Gold. Iron pyrites, FeS_2.

Fuller's Earth. A white variety of clay.

Green Vitriol. Ferrous sulphate.

Gypsum. Native calcium sulphate, $CaSO_4 \cdot 2H_2O$.

Hartshorn. An old name for ammonia, so called because made from the horns of deer.

Hypo. Sodium thiosulphate, used in photography as fixing bath and as an antichlor.

Iceland Spar. A transparent, crystallized variety of calcium carbonate.

Jeweler's Rouge. Ferric oxide, native, used in polishing and as a paint.

Kelp. A variety of seaweed. Also applied to the ashes derived by burning the seaweed.

Labarraque's Solution. Sodium hypochlorite, $NaClO$.

Lac Sulphuris. A fine white precipitate of sulphur in limewater.

Laughing Gas. Nitrous oxide N_2O.

Lime. Calcium oxide.

Limestone. Native calcium carbonate, uncrystallized.

Limewater. Calcium hydroxide solution.

Lunar Caustic. Silver nitrate in stick form containing small percentage of silver chloride.

Magnesia. Magnesium oxide.

Marble. Crystallized limestone.

Milk of Lime. Calcium hydroxide solution containing lime in suspension.

Minium. Red Lead, Pb_3O_4.

Naphtha. A low boiling gasoline obtained from petroleum.

Nitre. Potassium nitrate.

Nordhausen's Acid. Fuming sulphuric, $H_2S_2O_7$.

Oil of Vitriol. Sulphuric acid.

Opal. A variety of silica.

Paris Green. Copper aceto-arsenite.

Pearl Ash. Pure potassium carbonate.

Plaster of Paris. Monohydrated calcium sulphate, $CaSO_4 \cdot H_2O$.

Plastic Sulphur. Amorphous sulphur, prepared by pouring boiling sulphur into cold water.

Potash. Commercial potassium carbonate.

Powder of Algaroth. Impure antimony oxychloride.

Purple of Cassius. A purplish colored compound obtained by adding to a solution of gold chloride a small amount of stannous and stannic chloride.

Pyrites. Usually means iron pyrites, FeS_2. There is also a copper pyrites.

Quicklime. Lime.

Red Precipitate. Mercuric Oxide.

Sal Ammoniac. Ammonium chloride.

Sal Soda. Crystallized sodium carbonate.

Salt Cake. Sodium sulphate as obtained in the Leblanc process of making sal soda.

Saltpeter. Potassium nitrate.

Scheele's Green. Acid copper arsenite, $CuHAsO_3$.

Silica. Silicon dioxide.

Slaked Lime. Calcium hydroxide, formed by adding water to lime.

Smoky Quartz. A variety of quartz; silica, brown in color, sometimes almost black.

Soda. Usually cooking soda is meant. Sodium bicarbonate, $NaHCO_3$.

Subnitrate Bismuth. Bismuth oxynitrate, often sold as ''bismuth.'' $BiONO_3$.

Sugar of Lead. Lead acetate, $Pb(C_2H_3O_2)_2 \cdot 3H_2O$.

Vermilion. Artificial mercuric sulphide.

White Arsenic. Arsenic trioxide.

White Lead. Basic lead carbonate; a common white pigment.

White Vitriol. Crystallized zinc sulphate. $ZnSO_4 \cdot 7H_2O$.

Zinc White. Zinc oxide, ZnO. A common white pigment.

BIBLIOGRAPHY

There will come times when every student will wish to pursue further some line of thought suggested by the text. The following books will be found valuable inasmuch as they cover a wide range of practical subjects in chemistry; and with few exceptions they are not large works, are interestingly written, and not too technical.

Air, Water, and Food, *Richards and Woodman.* John Wiley & Sons, New York.

A Short History of Chemistry, *Venable.* D. C. Heath & Co., New York.

Bacteria, Yeasts, and Molds, *Conn.* Ginn & Co., Boston.

Chemical History of a Candle, *Faraday.* Harper & Bros., New York.

Chemistry in Its Relation to Daily Life, *Kahlenberg and Hart.* Macmillan Co., New York.

Chemistry of Common Life, *Johnston.* D. Appleton & Co., New York.

Chemistry of Everyday Life, *Lassar-Cohn.* J. B. Lippincott Co., Philadelphia.

Chemistry of Food and Nutrition, *Sherman.* Macmillan Co., New York.

Discovery of Oxygen, *Priestley.* Chemical Publishing Co., Easton, Pa.

Early History of Chlorine, Reprints. Chemical Publishing Co., Easton, Pa.

Essays in Historical Chemistry, *Thorpe.* Macmillan Co., New York.

Examination of the Urine, *Saxe.* W. B. Saunders Co., Philadelphia.

Foods and Their Adulterants, *Bruce.* D. Van Nostrand Co., New York.

Foods and Their Adulteration, *Wiley.* P. Blakiston's Son & Co., Philadelphia, Pa.

Food Preservatives, *Eccles.* D. Van Nostrand Co., New York.
Gases of the Atmosphere, *Ramsey.* Macmillan Co., New York.
Household Chemistry, *Vulte and Goodell.* Chemical Publishing Co., Easton, Pa.
Household Physics, *Lynde.*
Modern Bleaching Agents, *Bottler.* D. Van Nostrand Co., New York.
Physiological Chemistry, *Beebe and Buxton,* Macmillan Co., New York.
Pure Foods, *Olsen.* Ginn & Co., Boston.
Pure Water and How to Get It, *Hazen.* John Wiley & Sons, New York.
Sanitary and Applied Chemistry, *Bailey.* Macmillan Co., New York.
The Chemistry of Commerce, *Duncan.* Harper & Bros., New York.
Toxicology, *Dwight.* Lea Bros. & Co., Philadelphia.

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