GILBERT CHEMISTRY OUTFIT

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CHEMISTRY FOR BOYS

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THE BETHWOOD RESEARCH LABORATORY
Bethany, Connecticut

Edited by
TREAT B. JOHNSON
Yale University, Ph.B. 1898, Ph.D. 1901

and

ELBERT M. SHELTON
Oberlin College, A.B. 1917
Yale University, Ph.D. 1924

in collaboration with

ALFRED C. GILBERT, M. D.
Yale University 1909

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New York—Chicago—London
Prof. Johnson has been associated with the Chemistry Department of Yale University since 1898. He received the degree of Ph.B. from the Sheffield Scientific School of Yale in 1898, and the Ph.D. degree from Yale Graduate School in 1901. Since this later date he has been continually engaged at Yale in the teaching of organic chemistry and in the promotion and development of advanced research in the field of organic chemistry and Biochemistry.

About 75 graduate students have received their Ph.D. degree for research done under his direction and these specially trained men now hold positions in universities and industrial organizations in this country. Prof. Johnson’s publications in the field of organic chemistry number nearly 300 papers, and his pupils who have been granted the Ph.D. are constantly contributing to scientific and technical journals in various lines of activity.

Prof. Johnson is a member of the National Academy of Sciences, The National Research Council, The American Chemical Society, The American Institute of Chemists, The Connecticut Academy of Arts and Sciences and the American Society of Biological Chemists.

At the present time he is holder of the Sterling Chair of Organic Chemistry in the Graduate School of Yale University.
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INTRODUCTION

The object in writing this elementary book is to present the simpler fundamental concepts of the Science of Chemistry in a form which will appeal to boys, and arouse in them a desire to acquire an understanding and appreciation of some of the fundamental laws of nature. The subject matter has necessarily been arranged and presented in a style to stimulate the boy’s interest and curiosity without creating the feeling, on the part of the boy, that he is undertaking a laborious problem which will not give him pleasure. It is earnestly hoped that the subject matter will provide the opportunity for any boy to have a lot of fun in doing the many experiments, and by so doing, obtain an elementary knowledge of the principles upon which the Science of Chemistry is based.

A.C. Gilbert
ORIGIN OF THE WORD “CHEMISTRY”

The first literary work in which the word—“Chemistry”—is found was written by Plutarch, a Roman historian who lived from 46-120 A.D. In a treatise entitled—“Isis and Osiris”—that philosopher mentions that “Egypt” in the dialect of the country, was called the same name as the black of the eye, “Chemia,” and from this he infers that the word meant “Black” in the Egyptian language. Some science historians believe that our word “Chemistry” means “The Egyptian Art.” Others think that the word was coined to mean “The black art.” Still others think that the word meant “The dark or hidden art.” Another school of thinkers believes that the word has no connection with Egypt at all, but that it comes from the Hebrew word “Chaman,” meaning mystery. Another possible derivation, according to some historians, is from the Arabic word “Chema”—meaning to hide, hence “the Hidden Science.” In fact, a book of secrets was written in the time of the ancient Arabians called “Kemi.” Probably no one will ever know definitely which one of these possible derivations is the correct one.

ORIGIN OF CHEMISTRY AS A SCIENCE

According to some historians, the origin of chemistry as a science dates back to the time of Tubal Cain, the father of workers in metal. Credit is also given to Hermas, the Egyptian god of art and sciences. His son is said to have colonized Egypt, which was foremost in the knowledge of chemistry in those ancient days for they had developed the arts of making glass, pottery, colors, embalming fluids and other practical products to a high degree, and the early Egyptians can really be said, therefore, to have had an advanced knowledge of applied chemistry. Then Paracelsus, the Greek physician, carried the study along and discovered the influence of chemistry upon medicine in the treatment of human ills, and it was through him that the action of several inorganic salts upon the human system became known. Following this period a long time elapsed, hundreds of years, during which time contributions were spasmodically made by unknown workers in science, but which really had little influence upon the development of modern chemistry.

Chemistry, as we know it today, is one of the newest of our sciences, and yet it is one which offers the greatest opportunities of advancement, research and fame for those today who are interested in the fuller things of life. Centuries ago there was no such thing as chemistry. Chemistry was preceded by alchemy. Alchemists were superstitious men and were very often dishonest men. He was a groper for mysteries, and if it had not been for this interest in the mysteries of energy and matter, modern science would never have been born. We can now visualize the old alchemist working over his pots and retorts in crude laboratories and in dark caves. Shrouded in mysticism, and his activities kept secret, his imagination fired with zeal and exercising patience, and with the purpose of a religious fanatic, he sought to make or find the philosopher’s stone.

It was not until the early part of the eighteenth century that the scientist of the central European countries and the English Empire began to contribute fundamental knowledge which laid the foundation and paved the way for the development of this wonderful science. The Frenchman, Lavoisier (1743-94) may really be credited with being the father of modern chemistry.

There is hardly a science today that has greater economic influence, or holds more fascinating interest to scientists throughout the world than chemistry. If we are to unravel the secrets of our wonderful world and life, there is no science that will enable us to
understand and correctly interpret these hidden things of nature that most of us think are magical and mysterious, like a knowledge of chemistry.

No large and progressive manufacturing industry can cope with its competitors today without a trained chemist to advise and assist in its development and the analysis of the raw materials which it buys. The present-day physician without a knowledge of chemistry would be incompetent and unable to maintain an acceptable professional standing as a practitioner of medicine.

The great problems involved in the manufacture of synthetic drugs, dyes, perfumes, essential oils, of soil fertilization, and of the many substituted and artificial productions influencing modern civilization are every-day problems of chemistry. The regulation of our food supply calls for the services of thousands of experienced technicians who are employed as chemists by industry, municipalities and both our State and National governments. If we would have our country today improve its standards of living and at the same time accommodate itself to an increasing population, we must hereafter maintain on an even more liberal scale than ever before great laboratories of science devoted to the study of chemistry. The men and women working in these laboratories are among our priceless possessions. There is no sum that the world could not afford to pay these men who have that originality of mind and devotion and industry to carry forward in scientific advancement until its influence spreads to the comfort of every home. It was former President Coolidge who wrote as follows: “Wherever we look, the work of the chemist has raised the level of our civilization, and has increased the productive capacity of the nation.”

Probably most boys are interested in science because they just naturally think they will like science. This is a perfectly good and sufficient reason in itself. At the same time, a boy of intelligence who becomes interested in science would like to be reassured, no doubt, that science offers a really important field for service in the interests of human welfare. From the far-sighted point of view, the public is better off today than it was before science was developed, and so it always will be. Every boy and girl should be impressed with this fact and be made to realize that science creates jobs, and that its application makes life more comfortable and more interesting.

In order to illustrate this point of view, emphasis has been laid on experiments in this little manual which show the relationship between chemistry and its application to our chemical industries and to everyday life. There was a time when chemistry was regarded as being related to witchery and sorcery. Chemicals were formerly looked upon as deadly poisons and chemical reactions were associated with explosions. The men who practiced the science of chemistry had to do so in secret because they were regarded by the people with superstition and dread and as related to the devil.

Today conditions are entirely different. There is now no need for secrecy. A chemist is looked upon today as a professional man to be treated with respect, and there is a growing desire to know more about this science. To satisfy to some degree the youthful thirst for chemical knowledge, and to afford the pleasure to boys to be derived from the intelligent performance of simple experiments, is one of the aims of this manual. The second aim is to develop the power of scientific reasoning and to give to the boy an elementary knowledge of the fundamental principles upon which modern chemistry is based.

The experiments in this manual must be carried out with accuracy in order to obtain satisfactory results. Remember that nature is exacting in her methods of operation, and it is the problem of the scientist to seek the truth and operate according to the “rules of the
game,” so to speak, by careful experimentation. The author would therefore urge that you think out for yourself, when you are performing experiments, first as to what you are doing the experiment for, second, weigh carefully the results obtained, and third, draw some conclusions as to what the results really mean to you. It is by so doing that you will develop your imagination, and an investigative mind. The performance of your experiments will prove a pleasure to you, and at the same time you will contribute to your knowledge and also advance and develop the science of chemistry.

**WARNING!!**

Gilbert Chemistry Sets are not intended for children who cannot read and understand the accompanying Instruction Books.

Gilbert Chemistry Sets do not contain dangerous poisons and the chemicals mentioned in this manual are not embraced under the term “poisons.” They are perfectly safe to use if handled carefully and intelligently. They are not intended to be taken by mouth or swallowed, and no intelligent person would be expected to use them for such purposes. It is necessary, however, to emphasize the fact that carelessness on the part of the experimenter can always lead to trouble. The author suggests, therefore, that all experimentation be carried out cautiously and according to the directions, especially when manipulations like heating is involved; or when gases are evolved in the reactions. Before performing any experiments outlined in the manual, the following instructions should be read carefully and observed.

Before performing experiments, be sure to spread a thick layer of newspapers or other protective material over the table, so that hot liquids, candle grease, etc., will not injure the table.

Always read an experiment entirely through before starting to perform it. By following this rule many mistakes may be avoided.

Never point the open end of a test tube, while heating, at yourself or anyone nearby, as it may suddenly boil over, causing burns or injuring clothing. For the same reason never smell at the open end of a test tube while heating, or put your face near it.
CHEMISTRY CLASSIFICATION

Inorganic Chemistry

Metals, minerals, ores, etc., which are found in nature occurring in the crust of the earth, are classified as inorganic materials. They are not combustible in the sense that they can be burned like carbon to gaseous products. They represent a classification which was originally spoken of as mineral substances and are distinguished from those products or substances which originate directly or indirectly from living organisms. Iron, copper, glass and the ore pyrite, for example, are typical inorganic substances, and all materials of this nature are treated under a specific classification which we designate as inorganic chemistry.

Organic Chemistry

It was the French chemist, Lavoisier (1743-94) who showed that in spite of their great number, nearly all vegetable products occurring in nature are composed of three elements—carbon, hydrogen, and oxygen—whereas animal substances, which also consist, for the most part, of these same three elements, contain nitrogen, and in some cases phosphorus, sulphur and iodine. All such products were shown to be not only peculiar in their composition, but also were combustible. This discovery of Lavoisier and later workers led to the belief that all animal and vegetable substances in nature were produced under the influence of a vital force, and that their formation in nature was regulated by laws which were different from those which governed the formation of mineral substances. For this reason, therefore, compounds obtained from animals and plants, either directly or indirectly, were called organic compounds and a study of the products of this type was classified under the designation “Organic Chemistry.” This distinction between organic chemistry and inorganic chemistry was generally accepted until the year 1828, when the German chemist, Wohler, succeeded in preparing urea (an excretion product of animal organisms) by heating the inorganic salt, ammonium cyanate, a substance which might be considered to be inorganic, or mineral. This classic synthesis showed that the influence of a living organism was not necessary for the production of an organic substance—urea. As the science of chemistry was developed, it was soon found that a great many other so-called organic substances could be prepared in the laboratory by artificial methods and from materials of inorganic origin, and ultimately it came to be generally acknowledged that many of the processes which occur in animals and plants could very probably be carried out in the laboratory, and that the formation of an organic compound is probably not dependent at all on the help of any vital force than is that of an organic compound. Today this difference between the two classes of compounds has been recognized as an imaginary one, and the terms “organic chemistry” and “inorganic chemistry,” have, to a large degree, lost their original meanings. They do, however, serve to sub-divide the fields of chemistry into two groups which are characterized by their own special technique, and whose exploitation has led to products which have satisfied many human needs and produced a basis for important and basic chemical industries. The compounds of carbon compounds also are all related to one another and they differ widely in their general behavior from those of all other elements. Carbon compounds, therefore, form, in fact, a very distinct group of compounds, and it is therefore convenient to class them separately and to distinguish them by the term “organic.” Organic chemistry, therefore, is, according to modern interpretation, the chemistry of the carbon compounds.
PART I
The Chemists' Laboratory
and
How the Chemist Uses His Equipment

The chemist's work-room or laboratory has several special requirements if it is to be fully satisfactory. A room somewhat isolated to avoid interruption is desirable, especially if small children are around to stick inquisitive fingers into things. Good ventilation is necessary, and at least enough heat at all times to keep water solutions from freezing. While a capable chemist seldom spills anything, and, in spite of popular opinion, almost never has an explosion, it is better to have the laboratory plainly and simply furnished so that an accidental splash will do no damage. A plain wooden floor is better than a carpet, and concrete or linoleum are still better. The work table may be of plain lumber, with the top waxed frequently to protect it. A sink and a supply of running water are quite essential, but if he lacks these the ingenious boy chemist will find a way to provide himself with running water from a pail fitted with a siphon and hose. And you never will get too many shelves, cabinets and drawers for storage.

Now in picturing to you this ideal laboratory, we realize that few boys can have all this at once. In fact, your Gilbert Chemistry Set has been designed to be as far as possible a complete laboratory in itself. But we feel sure you will enjoy it more if you can at least select for it a secluded corner in den or kitchen, or even in the woodshed, cellar, or attic, where your apparatus may be left set up undisturbed and where there will be room to expand as you build or buy new equipment and supplies.

THE EQUIPMENT AND ITS USE

Good technique can only be acquired by careful self-training. Learn what use each piece of apparatus is intended for, and the best way to handle or use it. Begin at the start by having a place to keep each and every piece, and keep it clean and in its place. Be extremely careful not to contaminate your chemical supplies by getting even traces of one into the bottle with another. And watch to keep your chemicals replaced as soon as the supply runs low.

While you have not been furnished with dangerous and poisonous chemicals, nevertheless they are not intended to be taken into the mouth, and you should begin now to train yourself, not only never to taste anything in the laboratory, but to use caution in smelling.

THE SPATULA AND MEASURE

One measure of a dry chemical means as much as can be held in the spoon-shaped measure (Fig. 1). For transferring solid materials and for rough measuring the chemist uses a flat blade called a spatula. Your set has been equipped with an improved spatula having the flat blade at one end and a small spoon-shaped measure at the other. Even when made
of corrosion-resistant metals, a spatula is soon corroded by chemicals unless you wash and dry it immediately after use. A roll of inexpensive paper toweling is invaluable for this and similar purposes in your laboratory.

THE MEASURING SPOON

![Figure 2](image_url)

One teaspoonful of a dry chemical means as much as the spoon will hold after tapping it lightly. The teaspoon is also used for heating solids (Fig. 2).

TEST TUBES

![Figure 3](image_url)

WARNING — Never point the open end of a test tube, while heating, at yourself or anyone nearby, as it may suddenly boil over, causing burns or injuring clothing. For the same reason never smell at the open end of a test tube while heating, or put your face near it.

The test tubes in your set are not the miniature toy affairs sometimes put into chemistry sets, but practical test tubes made of especially strong, heat-resisting glass. Some skill is needed when heating liquids in a test tube to avoid sudden explosive formation of steam which may throw some of the liquid out of the tube.

EXPERIMENT 1. Heating a liquid in a test tube

Fill a test tube about one-third full with water and attach the test tube holder near the top of the tube. Hold the tube over the flame of an alcohol lamp, keeping it in a slanting position as shown in Figure 3 so that the heat strikes the side of the tube. Maintain a gentle
shaking motion to promote smooth and steady boiling. Even with this precaution, do not point the open end of the tube toward yourself or any other person while you are heating it.

If a test tube has been heated empty or with dry solid materials inside, do not pour water or any other liquid into the tube until it has cooled.

**TEST TUBE BRUSH**

A test tube brush has been furnished to help clean the test tubes. You will find that a little of an ordinary kitchen scouring powder on the brush will help greatly in cleaning them. Always clean the test tubes immediately after you are through using them so they will be clean and dry next time. Clean test tubes are very conveniently stored upside down on the pegs of your test tube rack.

![Test tube holder used as a stand.

Test tube holder as used in hand operating.

**FIG. 4**

**TEST TUBE HOLDER**

The Test Tube Holder can be used for two purposes: when heating mixtures in a test tube it sometimes becomes too hot to hold with the fingers, and it is recommended to always use the test tube holder. The Test Tube Holder can also be used as a stand. (See illustration, Fig. 4.)

**THE STIRRING ROD**

![Stirring rod](image)

A stirring rod (Figure 5) is a very convenient piece of apparatus for mixing a solution when dissolving a solid in a liquid. It is a solid glass rod, round at both ends. Always clean the rod with water before using it in different solutions.
PART II
Inorganic Chemistry and Its Commercial Application to the Industries

MATTER IN CHEMISTRY

Matter may be either an inorganic or an organic substance. Before one begins to think in the terms of chemistry, he ought to know first the difference between material and immaterial things. Material things are matter, and matter is something that occupies space; something that takes up room. It can be either inorganic or organic material. Immaterial things are not matter; for example, a thought is not matter; it does not take up room; it has neither length, breadth, nor thickness; you cannot feel, taste or see it. A good example of a material thing is air enveloping the earth; this has weight, and it takes up room. Water also is matter. In the form of a small raindrop, it has size, form, and weight; it occupies space. It is a material thing.

KINDS OF MATTER

Matter is found in different forms such as gas or vapor, liquid and solid, and many of the same substances of matter may be made to assume all the three different forms. Water, for example, is of common occurrence in nature as a liquid, but if the temperature falls low enough, as in winter weather, water is chilled and finally becomes a solid, which we recognize as ice. On the other hand if the temperature rises high enough, the water becomes invisible and turns into a gaseous state, which we utilize in the form of steam as a source of power in the steam engine. Water is an inorganic substance. The three forms of matter can also prevail among many organic compounds. For example, if one heats a piece of camphor gum in an evaporating dish or in a tin cup, he will observe the following phenomena: The solid particle of camphor turns to a clear liquid. In other words, the camphor, when first heated, passes from a solid into a liquid state by melting. On continued application of heat, the camphor will finally volatilize and become invisible. On leading the vapors of camphor over a cool surface, the organic vaporous material will solidify and deposit again as solid camphor. During all these physical changes there is no alteration in the chemical composition of the camphor. This same statement also applies to the inorganic material—water.

DIVISION OF MATTER

It is possible to divide inorganic and organic matter into very minute particles. Glass, for example, may be broken up into fine fragments, and even ground to a dust. In the manufacture of Portland cement we find a typical application of the production of fine particles of inorganic matter by intensive grinding of mineral substances. Every single particle of the dust of a pulverized substance represents the same composition as that of the original material before grinding. A wild animal running through a forest, like a fox or deer, may emit odious particles in his travels that cannot be seen by any human eye, yet the hound can easily pick up the scent and follow them for miles and for hours after the fox or deer has passed a given point. The odorous principle of a fragrant flower can be detected
by the sense of smell in an atmospheric dilution corresponding to a percentage of composition that is indeterminable.

**EXPERIMENT 2. Division of matter**

Take a pinch of common salt (sodium chloride) and dissolve it in water. Now taste the solution. You will be able to detect the characteristic taste of the salt in the solution, although you cannot see it with the human eye. Now add an equal volume of pure water to the salt solution. Mix well, and then taste the solution. You will find that you are still able to discern the taste of salt. Dilute once more with an equal volume of water and then taste again the resulting solution. Now you can imagine the thousands of particles of salt there must be in your water solution to enable you to detect it by the taste and yet not to see it.

**EXPERIMENT 3. Division of matter**

Drop into a clear dry test tube a crystal of iodine which may be obtained in any drug store, and insert a common cork lightly into the mouth of the test tube (Figure 6). Hold the test tube over an alcohol or candle flame and warm gently. Watch the beautiful purple gas that is formed and observe how it creeps upward toward the mouth of the test tube. Here you have another demonstration of extreme divisibility; the solid particles of iodine having been volatilized by heat and divided into thousands of small gaseous particles of iodine which are visible to the eye.

**INORGANIC AND ORGANIC MOLECULES**

Molecules are small particles of matter. The two foregoing experiments that we have asked you to perform have led chemists to the conclusion that ordinary matter is composed of particles and that these particles are so small and so minute in size that they cannot be
detected with the human eye or even under the magnification of the most powerful microscope. These sub-divisions into minute particles of matter have been designated as molecular in nature. As we proceed to experimentation in chemistry, we will speak of these different particles of matter as molecules, and we shall be instructed in accordance with a law of chemistry, which may be stated as follows: The smallest particle into which matter can be sub-divided without changing its chemical nature, is a molecule. Having adopted a designation—"molecule"—to define the smallest particle of any substance which has all of the properties of the whole substance, it is now easier to explain the physical difference between solids, liquids and gases.

**MOBILITY OF MOLECULES IN SOLIDS, LIQUIDS AND GASES**

In a solid substance, the chemist conceives molecules as being firmly held together. They are not free to move about to any great extent, and are assumed to have fixed positions. For this reason a solid substance retains its form or shape. Many substances assume definite crystalline form of great beauty. In crystals we have evidence to support the conclusion that the molecules are arranged in an orderly fashion and that it is due to this orderly arrangement of the molecules of both inorganic and organic substances that crystals assume such beautiful symmetry. We have no better illustration of variations in crystalline form than that revealed by snow flakes. In other words, the face of a crystal is composed theoretically of a layer of orderly arranged molecules or lattice structure of the particular substance under consideration. In a liquid, on the other hand, the molecules are assumed to be free to move about among themselves much more freely than is possible in a solid. For this reason liquids flow and assume the shape of the receptacle in which they are inclosed. Solids can be fractured by friction and ground into smaller sub-divisions, while a liquid will withstand great pressure and cannot be divided by a frictional force. Gas molecules are assumed to be entirely separate and mingle with each other and fly apart very widely when they are allowed to leave the space in which they are confined. In other words, the molecules are mobile, and due to this property, we speak of a gas as being volatile and easily diffused. The molecules of a gas move about much more rapidly than those of a liquid or a solid. To illustrate, the walls of a football are kept pushed out by the constant pressure and hammering of millions of air molecules that are enclosed within the walls of the football. Also the pressure within a steam boiler is caused by the molecules of water in the form of water vapor which press constantly against the sides of the boiler.

**PHYSICAL PROPERTIES OF MATTER**

**MASS AND VOLUME**

All matter occupies space. The displacement of space occupied is called volume. A bushel, a quart, a liter represent, respectively, a unit of space or a measure of volume of space occupied by a particular substance. The space occupied by a known weight of solid, liquid, or gas varies according to the density of the material. By specific gravity we mean the relation between the volume and the weight of a substance. Water is used as the standard, that is, 1 cubic centimeter of water at 4 degrees Centigrade weighs 1 gram. Thus, if we have 1 cubic centimeter of a substance which weighs 5 grams it has a specific gravity of 5.
The specific gravity of a substance often enables us to tell whether or not that substance has been adulterated. For example, a certain oil may have a specific gravity of 2. If the specific gravity when measured is 1.7, for example, the oil has been adulterated with some other substance.

**EXPERIMENT 4. To demonstrate the specific gravity of liquids**

Place a fresh egg in a glass of water and notice that it sinks to the bottom. Now remove the egg and dissolve 2 spoonfuls of salt in the water. Then put the egg into the salt solution and notice that it floats.

The reason why the egg floated in the salt solution was because we increased the specific gravity of the water beyond that of the egg. The specific gravity of a solution is always greater than that of the pure liquid. This is the reason why it is easier to swim in salt water than in fresh water.

**MALLEABILITY**

By malleability is meant having the property of being rolled out or flattened without fracture. This property is characteristic of many metals. Of all the metals, platinum and gold are the most malleable, and gold can be rolled into leaves so thin that it would take 300,000 of these leaves to make the thickness of one inch. Iron is a very malleable metal when hot, and can be moulded into many shapes and forms available for human needs. Many hundreds of men are employed daily in large steel mills in this country, rolling iron into steel rails for railroads, girders for buildings and bridges, sheets of metal for roofs, and construction of oil tanks, and many other applications made possible by the ingenuity of man.

**DUCTILITY**

Ductility means having the property of being drawn out into a fine thread or wire. Iron, copper, platinum, gold, and many other metals are characterized by this property. Ductile metals find wide application in industry, especially the electrical industry. It is interesting to know that the strength of some metals is increased by drawing them out into small wires and for this reason a drawn wire is stronger than an ordinary piece of metal of the same dimensions. Large cables made by twisting iron wire together are very much stronger than solid iron rods of the same size. Cables of this type are used in the construction of suspension bridges, of which the George Washington Bridge, extending over the Hudson River, near New York City, is an excellent example.

**BRITTLENESS**

By brittleness is meant having the property of crumbling into small particles when struck a heavy blow with a hammer. Excellent examples of a few substances which are brittle are ordinary glass, ivory, chalk, ice, egg shells, and almost all rock.

**ELASTICITY**

By elasticity is meant having the property of returning to the original form when it has been changed by some force applied to a substance. By the return to the original form, the molecules of the substance apparently tend to return to the places they formerly occupied before the change. Substances possessing this characteristic property are spoken of as being elastic substances. The one outstanding illustration of a substance having this unique
property is ordinary rubber. In the stretching of a piece of rubber we disturb the arrangement of the molecules of this material.

HARDNESS

A solid is said to be harder than another solid when it will scratch or make a mark on the other substance. For example, a diamond will scratch, and even cut, glass, because it is harder than glass. You can cut ordinary metallic lead with a knife blade because it is softer than the metal of the knife.

THE ELEMENTS AND CHEMICAL CHANGE

All of the changes which take place in chemical reactions are based on the actions of certain substances which the chemist calls “elements.” A boy or girl should, therefore, first acquire the correct meaning of this term if he or she is to perform understandingly chemical experiments. By elements the chemist means those substances which he is not able to break up into simpler substances. An element may be a solid, such as copper or iron; a liquid, such as mercury; or a gas, such as oxygen or hydrogen. It is also important to emphasize here the fact that some elements can exist in all of the three different physical forms. For example, ordinary iron is a solid, but will become a liquid if heated hot enough, or if heated at a very high temperature, it will become a gas. Mercury can be heated to form a gas, or it can be cooled to form a solid. The gas oxygen can be cooled to a liquid; or when cooled still further, to a solid. In all these physical changes of iron, mercury and oxygen, brought about by changes of temperature, we have not altered the elementary nature of these three substances.

More than ninety of these elements have been discovered to date, and we know that they combine in millions of different ways to form every substance that we know of on our earth. When elements combine with each other they form what the scientist calls “compounds.” When elements are converted into compounds, they lose their chemical identity, and we create new substances possessing different properties. Such phenomena we explain as chemical changes, and the chemist speaks of such chemical changes also as chemical reactions. For example, sulphur is an element and oxygen is an element. When the sulphur is heated it attracts to itself the element oxygen, and undergoes a chemical change. In other words, the sulphur and oxygen undergo a chemical reaction to form a compound which is a gas—sulphur dioxide. This gas finds wide commercial application as a bleaching agent, and also in the manufacture of electric refrigerators. The study of the elements and compounds, their properties, their chemical changes, and reactions, is called Chemistry.

KINDS OF CHEMICAL CHANGE

In general, there are four kinds of chemical changes which we need to consider, and every chemical reaction illustrated in this book will come under one of these changes. We will illustrate by experiments the four important types of chemical reactions of elements. First, we have that of Direct Union, or the combining of two elements to form a compound; secondly, we have what the chemist refers to as Decomposition or Degradation, which means the breaking down of a compound into its elements or into simpler substances; thirdly, what is called Double Decomposition or the exchange of elements in two or more substances to form new compounds; and fourthly, Substitution or Replacement, a reaction
in which one element takes the place of another in a compound, the substituted element being set free.

**CHEMICAL CHANGE THROUGH DEGRADATION BY HEAT**

**EXPERIMENT 5. Decomposition of sugar**

Put two measures of granulated or table sugar in a dry test tube and cautiously heat the tube over an alcohol lamp. Note the change in color of the sugar and its tendency to liquify. Watch the molten sugar and continue heating until it begins to char and turn black. Here we have a simple demonstration of degradation of an organic substance by heat. A chemical change has taken place by heating, leading to destruction of the sugar molecules with formation of water molecules and ordinary carbon. The identity of the carbon is disguised in the colorless sugar molecule, but is revealed when the sugar molecule undergoes decomposition. It is a very common property of many organic substances to decompose on heating. All organic animal matter decomposes on intense heating.

**THE ATMOSPHERE**

The air enveloping our earth is essentially a mixture of two elements—oxygen, which comprises about one-fifth of the air by volume, and nitrogen, four-fifths by volume. Actually, oxygen and nitrogen comprise 99 percent of the atmosphere by volume at sea level, the remaining one per cent being made up of a mixture of rare gases, namely, argon, helium and neon, mixed with traces of hydrogen and carbon dioxide. Oxygen is considered to be the most abundant of all the elements and most widely distributed. Eight-ninths of water by weight is combined oxygen. Such common materials as sandstone, quartz, limestone or marble, common brick, granite, clay and cement contain fully one-half their weight of oxygen. About two-thirds of the weight of the human body is oxygen. The total weight of oxygen in the land, the water, the atmosphere, and in living organisms may be regarded as very nearly equal to the combined weights of all the other elements.

**OXYGEN**

Oxygen of the air plays a very important role in our everyday life. We breathe this element into our lungs and from these organs it is carried by the blood-stream throughout the body to combine with the waste products of body metabolism. These waste materials are oxidized by the oxygen, carried in the blood stream to carbon dioxide which is carried back to the lungs by the blood and is there passed out into the air when we breathe. It is very essential, therefore, that we breathe in fresh air if we wish to enjoy good health. Pure oxygen is a very active element, and if it were not for the fact that the oxygen of the air is diluted with nitrogen gas, a very inactive substance, the world would soon burn up and all living organisms be destroyed.

Oxygen is said to support combustion, but the gas will not burn itself. A fire will not burn unless air rich in oxygen is constantly supplied so that the fuel can have plenty of oxygen to support combustion. Substances cannot burn without oxygen.
EXPERIMENT 6. To remove oxygen from the air

Place a candle in the center of an ordinary wash pan by allowing a little of the melted wax of the candle to fall on the pan to stick the candle firmly. Then pour into the pan two inches of water (Figure 7). Light the candle and place over it a mason or fruit jar. Be sure that the jar is high enough so that the flame does not come too close to the top of the jar.

You will notice that very soon the flame grows dim and finally dies out, the oxygen of the air within the jar having been entirely used up. Notice that the water begins to rise inside the jar and stands at a higher level than the water in the pan. This is because the oxygen was removed, forming a partial vacuum which drew the water up into the jar. The oxygen in the jar united with the carbon in the flame to form carbon dioxide, a gas which dissolves in water, and with hydrogen to form steam, which condenses to water. The gas remaining in the jar is nitrogen.

HYDROGEN PEROXIDE

Hydrogen peroxide is a chemical which every boy and girl should be familiar with. It is found in every “First-Aid Cabinet” and is a good antiseptic. Its antiseptic properties are based on its containing an extra oxygen atom which it gives up very easily. It is an unstable compound and sometimes the lowering of the oxygen content is due to the long time the antiseptic has been kept on the druggist’s shelf. Sometimes, also, this chemical is sold as a high grade peroxide solution when it actually never contained the required amount of excess oxygen. Hydrogen peroxide solution should never be taken by mouth.

EXPERIMENT 7. Behavior of hydrogen peroxide toward blood

Place a drop of blood on a small watch glass and then pour over the drop of blood a small quantity (5 drops) of hydrogen peroxide solution. Then mix the blood with the peroxide solution by stirring with a glass rod. Notice that the peroxide is decomposed with evolution of bubbles of oxygen. At the same time the red color of the blood is lost. The blood is destroyed by the action of the generated oxygen. Many forms of bacteria are killed by contact with hydrogen peroxide.
**OXIDATION**

Some compounds contain much oxygen and under suitable conditions readily give up part or all of their oxygen to other compounds. Such substances are called by chemists—oxidizing agents. In other words, by oxidation is meant the union of a substance with oxygen. During chemical oxidation heat is evolved and sometimes light.

Oxidation is an important chemical process. We obtain heat to warm our homes in winter, and power to run machinery in our factories by burning (oxidizing) wood, oil and coal. Our houses are lighted by burning (oxidizing) gas or kerosene, or by electricity that is generated by machinery run by burning (oxidizing) fuel. When gasoline is ignited and exploded in the cylinders of an automobile engine, the gasoline suddenly unites with the oxygen of the air which has been drawn into the cylinders. An ordinary house heating furnace is an oxidizing machine, and even man and all living organisms (animals) are likewise active oxidizing machines. By means of heat obtained by the process of oxidation metals can be melted. By power obtained from the process of oxidation our buildings are refrigerated and water can be frozen to artificial ice. Ice machines are of common commercial use today, and play an important part in the preservation of health. In fact, human life and all human activities depend upon some form of chemical oxidation and without oxygen our lives and all life activities of animals and plants would cease.

**CHEMICAL OXIDATION EXPERIMENTS**

**EXPERIMENT 8. Fire ink**

Place $1/2$ spoonful of potassium nitrate in a test tube and add $1/2$ inch of water. Warm over the candle for a minute to dissolve all the material.

Now write with this liquid upon some unglazed or porous paper, using a clean pen or a small brush. Be sure that the strokes are heavy and all lines are connecting. After the lines are thoroughly dry apply a lighted match or better a glowing spark to some of the writing. Blow out any flame that may result. If properly done, the spark will travel along the lines where the liquid has been applied, leaving the rest of the paper untouched. The potassium nitrate is a strong oxidizing agent.

This experiment is very mystifying and when performed in the dark is quite phenomenal and mysterious. The best results are obtained by using soft paper, and by making the lines heavy and connecting.

**EXPERIMENT 9. How to make a fuse**

A very good fuse can be made by soaking a cotton string in a solution of potassium nitrate or saltpeter for a few minutes and then allowing the string to dry. Allow the string to be suspended before drying. You can time your fuse by using the proper length of string. The nitrate solution is prepared by dissolving $1/2$ spoonful of potassium nitrate in a test tube containing $1/2$ inch of water, and then shaking until all is dissolved.

**EXPERIMENT 10. Oxidation of an element by means of a nitrate**

Heat on your spoon one measure of potassium nitrate until the salt is molten. Then drop a pinch of sulphur into the molten potassium nitrate and notice the sudden flash. The sulphur will be oxidized by the oxygen from the potassium nitrate to form sulphur dioxide. Note the odor of the burning sulphur. In the preceding experiment the burning of the cotton fuse leads to the formation of carbon dioxide, an odorless gas, while sulphur burns under similar conditions to give sulphur dioxide, having a characteristic penetrating odor.
EXPERIMENT 11. Oxidation of spices

Mix together 4 parts cinnamon, 3 parts of allspice, and 5 parts of ground cloves and grind together. Now add 8 parts of potassium nitrate to the above mixture but do not grind. Place some on a spoon and warm. Notice the odor—much like perfume. Now ignite this mixture and you will have a phenomenon as wonderful as a 4th of July night fireworks. A beautiful shower of colored fire will be the result.

EXPERIMENT 12. Suffocating a burning candle

Attach a short piece of a candle to a cork and float this on water in a tin pan about 2 or 3 inches deep. If the candle is top heavy fasten a nail or small iron weight to the underside of the cork. Light the candle and cover it with an inverted fruit can placed with its mouth on the base of the pan and under the water surface. As the candle burns it becomes paler and finally the flame dies out. You will notice that the water level in the jar is higher than at the beginning of the experiment. Some of the oxygen of the air has disappeared to support the combustion of the candle. Close the mouth of the fruit jar with a sheet of cardboard and set upright on the table.

EXPERIMENT 13. Testing for carbonic acid gas

Insert a lighted taper into the jar from the preceding experiment. The flame will be extinguished. The carbon dioxide formed by the burning candle will not support combustion.

EXPERIMENT 14. Burning sulphur

Repeat the candle experiment using some sulphur. Place the sulphur on a small tin lid resting on a cork. Ignite the sulphur and burn under the fruit jar. After the flame is extinguished then set the fruit can upright on a table and notice the color of the gas. Also suspend a moistened blue litmus paper inside the jar. Sulphur burns to form sulphur dioxide. Sulphur dioxide is soluble in water, forming an acid. This will turn the blue litmus paper red.

EXPERIMENT 15. Burning iron

Collect some fragments of metallic iron and free from all iron rust in order to obtain a clean metal surface. Tacks and small nuts and bolts are suitable. Wrap these in a piece of sheet cellophane and force firmly into the bottom of a medium sized test tube. Then invert this tube in a pan of water, support it by a clamp and let stand for several hours. The water will gradually rise to a higher level in the test tube, showing that air has been used up. The iron is slowly oxidized in contact with moist air and is changed by the oxygen of the air forming iron oxide. Examine the fragments of iron and note their appearance.

EXPERIMENT 16. Protecting iron from oxidation

Repeat the preceding experiment, but use fragments of iron which have been coated with collodion or some other material impervious to moist air. The water will not rise in the jar. You will observe that there is very little tendency here for the iron to undergo oxidation. Paint serves to preserve iron from oxidation and corrosion.

EXPERIMENT 17. Oxidation of zinc

Polish a strip of zinc metal and repeat the air oxidation experiment applied with iron fragments.
EXPERIMENT 18. Oxidation in the body

The changes taking place in our body are similar to the preceding changes of the burning candle and sulphur. We are built up of complex carbon compounds, some of which actually contain sulphur. When we breathe we inhale air through the lungs and here the oxygen of the air is picked up by the blood and carried where needed in the body. A burning process actually takes place internally, and the products of combustion are expelled through the lungs. Bubble the breath through a glass tube into a test tube of lime water. What happens? A white precipitate of calcium carbonate is formed, showing the presence of carbon dioxide.

EXPERIMENT 19. Combustion of charcoal

Heat three measures of potassium nitrate in a dry test tube over an alcohol lamp until the salt crystals liquify. Holding tube vertically then drop into the molten salt some specks of charcoal. They will take fire immediately. The nitrate furnished oxygen to burn carbon.

EXPERIMENT 20. Burning sulphur

Repeat the preceding experiment with sulphur. This will burn in the presence of potassium nitrate, forming sulphur dioxide, which will be detected by its characteristic odor.

EXPERIMENT 21. Burning paper

Repeat the above experiment with fragments of dry filter paper fiber.

EXPERIMENT 22. Oxidizing copper

Insert into some molten potassium nitrate a piece of copper wire. Note the change on continued heating over an alcohol lamp.

EXPERIMENT 23. Oxidizing iron

Repeat the above experiment using a piece of iron wire.

EXPERIMENT 24. Oxidizing aluminum

Repeat the above experiment using a small piece of aluminum foil or wire.

EXPERIMENT 25. Oxidizing nickel

Repeat the above experiment using a piece of nickel wire.

EXPERIMENT 26. Oxidizing zinc

Repeat the above experiment using some granules of granulated zinc metal.

EXPERIMENT 27. Oxidizing silver

Repeat the above experiment using a piece of polished silver metal.

EXPERIMENT 28. Asbestos insulation

Repeat the preceding molten potassium nitrate experiment with some asbestos fibers. What happens?

EXPERIMENT 29. Cotton fiber

Repeat the above experiment with cotton fiber. Which is the best fire insulating material, asbestos or cotton fiber?

PROTECTION AGAINST FIRE

Intensive oxidation of combustible material leads to generation of heat and, as a final result, to a conflagration. Cloth, wood, paper and other substances may be rendered fire-
proof by treating them with the proper chemicals. Ammonium chloride or sal ammoniac (NH₄Cl) is a cheap salt which can be used for this purpose. The article to be fireproofed is dipped into or soaked in a strong aqueous solution of ammonium chloride and then dried. When such treated material is heated, the ammonium chloride is decomposed with liberation of ammonia and hydrochloric acid, and a fire is prevented, as neither the ammonia or hydrochloric acid will support combustion. When they are generated they smother the flame and conflagration is prevented. The curtains and scenery of theaters and tapestries in public buildings are fireproofed as a protection against fires. Fireproofed wood finds important commercial use as a construction material. Such chemically treated materials cannot be set on fire by sparks or flames. Tin salts find commercial application in fireproofing.

EXPERIMENT 30. To fireproof cloth or paper

Take a strip of paper or linen and immerse it in a solution made by dissolving one teaspoonful of ammonium chloride in a test tube 1/3 full of water. When the paper or linen is dry, try to light it with a match. You will see that it burns while held in the flame but will go out just as soon as the flame is removed.

EXPERIMENT 31. To fireproof wood

Wood is also treated sometimes with a strong ammonium chloride solution. Another way to fireproof wood is to paint it with water glass solution.

Holding a match by the head, dip the other end in a sodium silicate solution (water glass). Allow the coating to dry for twenty minutes, then light the match. The flames will go out just as soon as it reaches the portion that has been dipped in the water glass solution.

EXPERIMENT 32. Fireproofing cloth

Cloth or other inflammable substances may be fireproofed by treating them with chemicals which when heated give off vapors that smother the flame.

Dissolve 12 measures of ammonium chloride in a test tube 1/3 full of water. Put a piece of cotton cloth 2 or 3 inches square in the bottom of a glass and pour the liquid in the test tube over it. Stir the cloth around until it is wet through, then let it dry and try to light it with a match. You will find that it will burn while held in the flame, but just as soon as the match flame is removed it will go out.

EXPERIMENT 33. Fireproofing with sodium silicate

Sodium silicate solution or water glass is often used for fireproofing. Wood is frequently fireproofed by means of sodium silicate. This liquid if applied to paper or cloth will cause it to become stiff when it dries, so it is not suitable for these materials.

Hold a match by the head and dip the other end into a solution of water glass (sodium silicate solution). Let the coating which is obtained dry about 15 minutes then light the match. There will be no danger of burning your fingers, for the flame will go out as soon as it reaches the water glass.

HYDROGEN

Hydrogen is one of the most interesting and important gases with which the chemist has to deal. It is, however, a dangerous gas to be used for experimentation by unskilled workers, and, therefore, the authors of this manual do not recommend its use by boys and girls. It is very explosive. Hydrogen is a colorless, odorless and tasteless gas. It is the
lightest substance known, being 14.5 times as light as air, 11,160 times as light as water, and 151,700 times as light as the metal mercury. It enters into the composition of all plants and animals. This element constitutes a large part of our coal, wood and petroleum. But the great storehouse of hydrogen in the world is in the vast amounts of water which occur in nature. Hydrogen occurs in the free state in the gases from some volcanoes, in many natural gas wells, and in the atmosphere of the sun and of some of the fixed stars.

Fig. 8

Because of its lightness, hydrogen is used for filling airships, dirigibles and balloons (Figure 8). During the last World War, hydrogen was used in enormous quantities, and was generated cheaply by treating the metal aluminum with sodium hydroxide. These materials were economical to use in large quantities and could be easily transported from place to place.

HELIUM AND AVIATION

Owing to the explosive nature of hydrogen gas it is not as widely used today as formerly for inflation of dirigibles and balloons. The gas helium, which is non-combustible, is being substituted for this purpose. The wreck of dirigibles has demonstrated the danger of using hydrogen as a buoyant gas in airships. A leak in a gas bag is sufficient to cause the destruction of a dirigible. In order to avoid this danger, the gas helium is now substituted for hydrogen, and is undoubtedly the only safe gas for use in airships or in inflating balloons. The discovery of helium is really one of the romances of science. The United States is fortunate in having supplies of natural gas in the State of Texas and in other parts of this country which contain sufficient helium to allow of its separation on a commercial scale. Helium, discovered previously in connection with the rare gases of the atmosphere, is surpassed only by hydrogen in lightness of weight, but it is superior to hydrogen in that it is non-inflammable.
NITROGEN

Nitrogen is a colorless, tasteless gas. It forms four-fifths of the bulk of the air. Chemically speaking, this is a very inactive gas, and if it were not for its presence in the air life on the earth would be destroyed. This gas dilutes the oxygen of the air, thereby preventing destruction by oxidation of living and inanimate material. Nitrogen is slightly lighter than air. Since nitrogen is a very inactive element, it combines with few other elements. However, those elements with which it combines form very interesting classes of compounds. Many of the compounds containing nitrogen occupy an outstanding position in chemical industry. The fact that nitrogen is a very inactive element would lead one to think that its compounds would be unstable and would decompose easily. This is true, and most of the high explosives used during military operations today are nitrogen compounds. Many of the most highly explosive substances are compounds of nitrogen with hydrogen, oxygen and sulphur. The force of an explosion is due to the tremendous volume of gases that are simultaneously formed when an explosive compound is detonated in a cannon or a shell. Gunpowder, nitroglycerine, nitrocellulose, or gun cotton, picric acid, trinitrotoluene (T.N.T.) and tetranitroaniline (T.N.A.) are some very common high explosives of nitrogen employed in military operations. A peace time use of nitrogen is in explosives as in the form of dynamite and nitroglycerine.

Much can be said about nitrogen and its services both in peace and war. As a necessary constituent of protein, this element stands among the first of the 92 elements in every-day importance. Because nitrogen is needed by the animal body, there must be a constant source of supply of this element for growing plants, since animals obtain their nitrogen supply from plants or from other animals which have in turn received nitrogen from plants. Plants obtain their nitrogen from the soil, soil nitrogen having been built up by the action of bacteria which are capable of fixing nitrogen of the air, or by the addition of fertilizers containing nitrogen. Nitrogen also features in many other industries, among them lacquer, coated textiles and plastics.

Nitrogen combines with oxygen to form several oxides. Nitric acid (HNO₃) is a compound of nitrogen with hydrogen and oxygen. This important acid is really the basis of most explosives containing nitrogen. It is also used in the manufacture of such commercial products as dyes and fertilizers. Nitric acid is manufactured on a commercial scale by treating chili saltpetre with sulphuric acid. This acid, and also ammonia, are manufactured today in enormous quantities from nitrogen of the atmosphere.

EXPERIMENT 34. Preparation of nitric acid

Put 4 measures of potassium nitrate and 4 measures of sodium bisulphate in a test tube. Add 4 or 5 drops of water. Moisten a piece of blue litmus paper and place it over the mouth of the tube. Now heat the test tube slowly over an alcohol lamp, and notice that the blue litmus paper turns red. Remove the test tube from the flame and smell cautiously, the fumes that are given off. These are nitric acid fumes and if they were led into water they would dissolve immediately, giving what we speak of as nitric acid solution. Potassium nitrate is a salt of nitric acid and when it reacts with the sodium bisulphate the free nitric acid is liberated.

EXPERIMENT 35. Nitrogen from the air

Repeat experiment 6 and remove all oxygen from air with a burning candle. Remove the jar from the pan by placing a small glass plate or a piece of glazed cardboard over the
mouth of the jar while under water. Set the bottle right side up, keeping the cover on so as not to lose any of the nitrogen. Light a splinter of wood and, removing the cover from the mouth of the jar containing nitrogen, plunge the splinter into the jar. Notice that the flame goes out, showing that nitrogen does not support combustion. Perform a similar combustion experiment by plunging a burning splinter into a jar of ordinary air.

AMMONIA

Every boy and girl is more or less familiar with the sharp and characteristic odor of ammonia. This chemical serves a great many practical purposes. In the household at the kitchen sink or in the bathroom it is used for cleaning purposes and for softening water. Ammonium carbonate, a salt which readily gives up its ammonia fumes under ordinary temperatures, is commonly used as smelling or aromatic salts. Ammonia gas is very soluble in water, and the aqueous solution—ammonia water—is the form in which it is commonly met with in the trade. Ammonia gas is condensed and shipped in enormous quantities today in iron cylinders. Ammonia in this form finds a wide use in artificial refrigeration. Formerly most of the ammonia of commerce was obtained from the destructive distillation of coal. It is a valuable by-product in the manufacture of illuminating gas. Today the gas is made in large quantities synthetically by combining nitrogen of the air with hydrogen.

EXPERIMENT 36. Preparation of ammonia

Put 2 measures of sodium carbonate and 2 measures of ammonium chloride in a test tube, add 10 drops of water and heat gently. Remove the test tube from the flame and notice the smell of ammonia in the mouth of the test tube. Place a strip of moistened red litmus paper over the mouth of the test tube and notice the change of color in the paper. It will turn blue. Any ammonium salt when heated in the presence of a base or alkali (lime water, sodium carbonate, and sodium hydroxide) will give off free ammonia gas and this reaction is used as a test for the ammonium group (NH₄⁺) in a compound. If the gas produced by heating the above mixture is passed into cold water, it is dissolved and ammonium hydroxide is formed.

EXPERIMENT 37. Formation of ammonia by decomposition of organic matter

Most organic matter contains nitrogen and when heated in the presence of an inorganic base, like calcium oxide, the nitrogen is partially liberated in the form of ammonia (NH₃). Ammonia was first prepared by this method and was called “Spirits of Hartshorn.”

Place a small quantity of wool, hair, silk or finger nail clippings in a test tube, and add 3 measures of calcium oxide and 5-6 drops of water. Place a small strip of moistened red litmus paper over the mouth of the tube and gently heat the tube over a flame. Notice that the red litmus paper turns blue, showing that a volatile base is formed. Remove the tube from the flame and smell at the mouth of the tube. You will recognize the odor of ammonia if the experiment is properly conducted.

EXPERIMENT 38. Dissociation of an ammonium salt

Put one measure of ammonium chloride in a clean dry test tube and heat slowly over a flame. Notice that the dry salt (NH₄Cl) passes into the vapor state and then condenses again on reaching the cooler part of the tube to form again solid ammonium chloride. What really takes place when heat is applied is that the ammonium chloride is split up into molecules of ammonia (NH₃) and hydrochloric acid (HCl), which re-combine in the cool part of the tube to form again solid ammonium chloride.
WATER

At ordinary temperatures pure water is a tasteless, odorless, transparent liquid: colorless in thin layers, but distinctly blue when seen in large masses. It is about 773 times heavier than air.

Water consists of two elements—both gases—hydrogen and oxygen, and they occur in the proportion of 89 per cent of oxygen and 11 per cent of hydrogen by weight. By volume, water consists of two parts of hydrogen to one part of oxygen.

Water occurs very abundantly throughout the earth. Vast areas of the colder regions of the globe are covered with it in the form of ice, while in the liquid state it covers about five-sevenths of the earth’s surface, reaching in some places to a depth of nearly six miles. Large quantities occur in the soil, and as a vapor it is an essential constituent of the atmosphere. More than half the weight of living organisms consist of water. A great many substances dissolve in water, so that water is known as a very good solvent. A substance is said to be dissolved when none of the particles of the substance can be seen in the liquid nor separated from the liquid by filtering. A dissolved substance can usually be recovered from a liquid by evaporating the liquid.

The importance of water in the growth of plants can be judged by the fact that from 30 to 120 gallons of water are required by an ordinary plant for the production of each pound of dry substance present. The greater part of this water which is taken in by the roots is given off by the leaves. The stream thus maintained serves to keep the plant cells fully distended thereby preserving the form of the plant, and enabling it to carry on its vital processes. Even though the largest proportion of the water taken in during the growing life of a plant is given off through its leaves, a considerable amount is retained. In succulent plants, about 90 per cent of the complete weight of the plant is water, this water being an actual part of the organism. In woody plants the percentage of water present in the organism is less, although even in this case we find this important compound an essential part of the living cell. With animals, water is quite as essential as it is with plants. About three-fourths of the total weight of the human organism is water, and about two quarts of drinking water a day, besides that which is present in our various liquid and solid foods are recommended to keep human beings in good physical condition.

<table>
<thead>
<tr>
<th></th>
<th><strong>Hard Water</strong></th>
<th><strong>Soft Water</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>With soap</td>
<td>Forms soap curds, and makes cleaning difficult.</td>
<td>Produces luxurious lather easily.</td>
</tr>
<tr>
<td>In bathing</td>
<td>Makes skin drawn, clogs the pores, preventing proper elimination of poisons by the skin.</td>
<td>Keeps skin soft and clean. Keeps pores free.</td>
</tr>
<tr>
<td>In shampooing</td>
<td>Deposits soap curds in hair, dulling lustre.</td>
<td>Makes hair clean and glistening.</td>
</tr>
<tr>
<td>In beauty culture</td>
<td>Makes it impossible to thoroughly cleanse skin.</td>
<td>Keeps skin glowingly clean and free from the blemishes.</td>
</tr>
<tr>
<td>In shaving</td>
<td>Makes a water-proof coating of soap curds around each whisker, causes razor blade to be dulled.</td>
<td>Thoroughly softens the toughest beard. Makes shaving easy—makes blades last longer.</td>
</tr>
<tr>
<td>In washing dishes</td>
<td>Causes streaks on china and glassware.</td>
<td>Dishes can just be drained clean. Many pieces do not need to be touched by a towel.</td>
</tr>
<tr>
<td>In removing grease</td>
<td>Makes work difficult.</td>
<td>Cuts grease like magic.</td>
</tr>
<tr>
<td>In home laundering</td>
<td><strong>Hard Water</strong></td>
<td><strong>Soft Water</strong></td>
</tr>
<tr>
<td>--------------------</td>
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</tr>
<tr>
<td>Wastes soap, discolors clothes, often necessitates extra hard washing.</td>
<td>Saves 50-80% of soap formerly used. Makes clothes soft, sweet, clean. Prolongs their life.</td>
<td></td>
</tr>
<tr>
<td>Calls for hard scouring—harms finish.</td>
<td>Preserves lustre.</td>
<td></td>
</tr>
</tbody>
</table>

| In pipes | Scale chokes down flow of water. Makes faucets drip. | Keeps pipes free from scales. Faucets seat tightly. |
| In water heater | Deposits rock-like scale in coil. Fuel is wasted. | Coils last longer. Minimum of fuel is consumed. |
| In steam boilers | Wastes fuel. Needs a long time for steam to come up. | Saves fuel. Steams quickly. |
| In automobile radiators | Will eventually clog fine tubes, causing overheating, boiling away of water. | Keeps radiator in efficient condition. Keeps motor operating at proper temperature. |
| In making pie crust | Tends to make crust tough. | Makes crust flaky and tender. |
| In cooking green vegetables | Toughens them, causes loss of flavor. | Keeps them tender with all natural freshness. Need less cooking. Makes them taste better. |
| In making tea and coffee | Impairs flavor. | A water softener like permutet removes calcium and magnesium. |
| For drinking | Hard water is unpleasantly flavored. | |

| For hygienic cleanliness | Makes it hard to remove dirt and foreign matter. Prevents thorough cleaning. | Cleans thoroughly and easily. Insures absolute cleanliness. |

**DISSOCIATION OF WATER INTO THE ELEMENTS OXYGEN AND HYDROGEN**

**EXPERIMENT 39. Decomposition of water by an electric current (electrolysis)**

It can be definitely proven that water is composed of two gases—namely, hydrogen and oxygen. For this experiment you will need two or three good dry cells, a shallow dish, some insulated copper wire, two test tubes and two pieces of arc light carbon or clean lead.

The apparatus is set up as shown in the illustration (Figure 9). The cells are connected together in series with copper wire by joining the carbon binding post of one cell to the zinc binding post of the other cell. To the free zinc and carbon posts of the end cells attach the long pieces of copper wires and fasten to the free ends of the wires the pieces of arc light carbon or lead, having previously scraped the free ends of the wire with a knife to insure a clean surface.

Now fill the pan about half full of a solution of sodium bisulphate, using one teaspoonful of the compound to each glass of water required. Fill two test tubes with this solution, close the mouths with the thumbs and invert them upside down in the pan, being careful not to allow any bubbles of air to get into them.
Now put one of the carbon or lead electrodes under each test tube, being careful not to allow any air in the tubes. Notice that immediately bubbles of gas begin to rise in each test tube from the carbon or lead electrodes and gradually force the water down out of the mouth of the tubes. Also notice that there is twice as much gas formed in one tube as in the other. This is because water is composed of two volumes of hydrogen to one volume of oxygen. The electrode at which the hydrogen is liberated is the negative electrode or cathode, and the electrode at which the oxygen is liberated is the positive electrode or anode.

**EXPLANATION OF THE ELECTROLYSIS EXPERIMENT**

Hydrogen, when in solution as an ion, has a positive charge of electricity. When an electric current is passed through the solution, the positive hydrogen is attracted to the negative electrode or cathode where it loses its charge of electricity and is given off as a gas.

Oxygen, on the other hand, is formed in the solution through chemical reaction, and is liberated at the positive electrode or anode. Being only very slightly soluble in water, it is also given off as a gas.

Sodium bisulphate is added to make the water a conductor of electricity, since pure water itself is a very poor conductor.

**AQUEOUS SOLUTION**

**EXPERIMENT 40. A soluble substance**

Dissolve one or two teaspoonfuls of common salt in a glass of water. Notice that you can no longer see the salt. If this liquid was filtered, you would find that nothing would remain on the filter paper.
Pour the solution into a clean pan and heat on a stove until all the water is driven off. Notice that a white solid remains. Allow this to cool and taste a little of the solid. It is the same salt you dissolved in the water, proving that the salt when in solution had undergone a physical change only.

**EXPERIMENT 41. An insoluble substance**

Try to dissolve 1 or 2 measures of sulphur in a test tube half full of water. Shake well and notice that the sulphur remains in the solid state.
Filter off the solid sulphur and evaporate the filtrate or the liquid remaining to dryness in a small pan or tin cup. Notice that nothing remains, proving that sulphur is insoluble in water.

**EXPERIMENT 42. Separation of starch from sugar**

Prepare a mixed solution of sugar and starch and transfer to a cellophane or parchment bag. Suspend in a jar of water and sugar will diffuse through the membrane into the outside liquid. Taste the water after a few hours and you can detect the sugar by the taste. Starch will not diffuse through the parchment into the outside solution. To prove this, test some of the outside solution with starch-iodide paper. (This is made by dipping a piece of paper in iodine solution.) If starch is present a blue coloration will be produced. By changing the outside water several times all the sugar can be separated from the starch in the cellophane or parchment bag.

**EXPERIMENT 43. Separating sugar from a protein**

Repeat the above experiment using a solution of egg white and sugar. Sugar will diffuse through the membrane. Like starch the egg protein will not diffuse through the membrane.

**CHEMICAL ACTION IN WATER SOLUTION**

Most chemicals, as a rule, do not interact when brought together in the dry form. Their molecules are inert and need to be activated before a chemical change can take place. When water is present so that solution can take place they then react readily. By solution in water the molecules are changed or activated, and the particles of the compounds are brought much closer together. Other solvents besides water can be used as a solvent to promote chemical change. For example, liquid ammonia can serve as a solvent for carrying out many interesting reactions that cannot be produced in water solution. Alcohols, acetone, benzene and other organic reagents are used in place of water as solvents for carrying out organic reactions. The organic chemist and inorganic chemist apply an entirely different technique in accomplishing chemical reactions.

**EXPERIMENT 44. Promoting chemical reaction by solution**

Mix together on a sheet of paper \( \frac{1}{2} \) spoonful of sodium bicarbonate (baking soda) and \( \frac{1}{2} \) spoonful of tartaric acid. Notice that there is no reaction.
Transfer this mixture to a test tube and add a few drops of water. A violent reaction results with the liberation of carbon dioxide gas, thereby proving that water is necessary to promote chemical reaction between these substances.
EXPERIMENT 45. Extinguishing a burning candle

Place a burning candle in the bottom of a pint fruit jar. Then drop a spoonful of dry ice to the bottom of the jar. Notice what happens when the dry ice turns to gas. What is dry ice?

EXPERIMENT 46. Burning sulphur

Repeat the preceding experiment, substituting burning sulphur for the candle.

EXPERIMENT 47. Floating a sunken ship

Place a spoonful of dry ice in a thin rubber bag and tie with a silk thread so that gas will not escape. Then attach a weight to the bag so that it will sink to the bottom of the jar of water. Note the result as the solid dry ice gasifies inside the rubber bag. The bag will finally float. How do you explain this?

EXPERIMENT 48. A miniature gas volcano

Take a heavy walled salt cellar and fill with dry ice, then place in upright position on the bottom of a tall glass jar filled with water. As the dry ice vaporizes the gas will rush through the openings of the salt cellar lid and the bubbles will travel to the surface of the water. Hold an electric bulb back of the jar of water during the bubbling.

ENDOTHERMIC AND EXOTHERMIC CHANGES

Some compounds give off heat when they dissolve in water. This is an exothermic change. Other compounds absorb or take up heat when they dissolve. This is an endothermic change.

EXPERIMENT 49. Lowering of temperature by solution

Fill a test tube half full of water, and notice the temperature by feeling of the test tube with the face or hand. Then add \(\frac{1}{2}\) spoonful of ammonium chloride and shake well to dissolve the salt. Again feel of the test tube and notice the change of temperature.

Compounds, like ammonium chloride, sodium nitrate and many others have what is known as a negative heat of solution (endothermic). That is, they absorb heat from water when dissolved in it, thereby lowering the temperature or cooling the water.

Compounds like magnesium sulphate, sodium hydroxide, and some others have a positive heat of solution (exothermic). That is, they give off heat when dissolved in water.

ARTIFICIAL REFRIGERATION

The application of the so-called negative heat of solution of common salt is made use of in the ice-salt freezing mixture so commonly used for making ice cream. Common salt just like ammonium chloride lowers the temperature of water when dissolved in it (endothermic change). Therefore, when salt is added to a mixture of ice and water whose temperature is just at the freezing point, the salt dissolves and in doing so, lowers the temperature of the solution several degrees below freezing, thereby affording us a very convenient freezing mixture.

EXPERIMENT 50. How to make a freezing mixture

Mix together a glass full of cracked ice and \(\frac{1}{2}\) glass full of salt.
Try the effect of this freezing mixture upon water by placing a test tube half full of water in it and allowing to stand for several minutes. Notice that the water in the test tube will freeze to solid ice after a short time.

CHANGING THE FREEZING AND BOILING POINTS

It is easily demonstrated that when a substance is dissolved in water the freezing point of the resulting solution is lower than the freezing point of water. This is the reason why salt is sometimes thrown on slippery sidewalks. It melts the ice by lowering the freezing point of the water.

It can also be shown that when a substance is dissolved in water, the boiling point of the resulting solution is higher than that of pure water.

EXPERIMENT 51. Solution lowers the freezing point of water

Make a freezing mixture as shown in the preceding experiment. Now add a spoonful of common salt to a test tube half full of water and shake until dissolved. Place this test tube of salt solution with another test tube half full of water in the freezing mixture and allow to stand. Note the change in temperature.

Notice that the water freezes but that the salt solution does not, thereby proving that solution lowers the freezing point of water.

EXPERIMENT 52. Solution raises the boiling point of water

Make a salt solution by dissolving a spoonful of salt in a test tube half full of water. Now hold this solution together with a test tube half full of water over an alcohol lamp, giving each about the same amount of heat. Notice that the water will boil before the salt solution does, thereby proving that solution raises the boiling point of water.

SUPERCOOLING

It is possible to cool a liquid below its freezing point. Water, for example, can be cooled below its freezing point, 32 degrees Fahrenheit or 0 degrees Centigrade, and still remain a liquid. When in this state, water is said to be undercooled.

EXPERIMENT 53. Undercooled water

Make a freezing mixture as explained in previous experiments. Place in the freezing mixture a test tube ⅓ full of water and keep the test tube quiet.

The temperature of the water in the tube may go down as far as 8 to 10 degrees below 0° degrees Centigrade or between 18 and 14 degrees Fahrenheit, and the water still remains in the liquid form.

If a small crystal of ice is now dropped into the test tube or the water in the test tube stirred, it will immediately freeze, the temperature then rising to the freezing point 0 degrees Centigrade or 32 degrees Fahrenheit.

DEGREE OF SOLUBILITY IN WATER

Most substances dissolve more readily in hot water than in cold water. There are a few exceptions, however, calcium hydroxide being a good example of a substance which is more soluble in cold water than in hot water.

EXPERIMENT 54. Effect of temperature on solubility

Put 7 measures of nickel ammonium sulphate in a test tube ¼ full of water and shake well. Notice that some of the solid remains undissolved. Now heat the tube slowly and
notice that all the solid goes into solution, showing that some substances are more soluble in hot water than in cold water.

Allow the test tube to cool undisturbed and notice the beautiful green crystals of nickel ammonium sulphate that separate out on cooling.

EXPERIMENT 55. Temperatures effect on solubility

Add 1 measure of calcium oxide to a test tube full of water. Shake several times and allow the tube to stand until the liquid becomes clear. Pour some of this clear liquid into another test tube and heat slowly over a flame. Notice that the liquid becomes cloudy or turbid, proving that calcium hydroxide which was formed when calcium oxide was added to the water is less soluble in hot water than in cold water.

EXPERIMENT 56. Diffusion

Fill a clean glass nearly full of clear water and let it stand for a minute or two to become quiet. Now add a small quantity of mixed dyes and watch closely what occurs.

As the substance dissolves the color seems to flow out of the small crystals, gradually spreading over the bottom of the glass. After a few minutes the color will begin to diffuse upward through the liquid until finally after several hours the entire solution will be a uniform color.

EXPERIMENT 57. Testing for acidity

Moisten a piece of blue litmus paper with a drop of the water you are testing. If the blue litmus paper turns red or pink, the water is slightly acid.

EXPERIMENT 58. Testing for lime

To a test tube of water add 2 measures of sodium carbonate and shake until dissolved. If the water, after standing a while, shows a white turbidity it contains a considerable portion of lime.

EXPERIMENT 59. Testing for carbon dioxide

Make up a solution of lime water by adding half a measure of calcium oxide to half a test tube of water. Shake well and let settle for a few minutes. Add to a test tube of water which is to be tested a few drops of this clear lime water. If a white turbidity is formed the water contains carbon dioxide.

The presence of carbon dioxide in water causes it to effervesce and gives it a sparkling taste. Soda water and many bottled mineral waters contain carbon dioxide.

EXPERIMENT 60. Testing for sulphur

Sulphur is present in some mineral waters in the form of hydrogen sulphide. It may be detected even if in very small quantities by dropping in the water a small piece of sulphide test paper. If sulphides are present the paper will turn black or brown.

EXPERIMENT 61. The boiling point of water; compared with salt

Dissolve 10 measures of common salt in a test tube half full of water and fill another test tube half full of plain water. Now heat these two test tubes over a candle or alcohol lamp flame. Hold them so that each tube will get just the same amount of heat. You will find that the water will boil before the salt solution does. Hold the tubes carefully so the boiling water will not spurt out on you.
Many compounds contain chemically combined water. Water occurring in compounds in this way is known as water of crystallization. Ferrous sulphate, nickel sulphate, and copper sulphate, for example, contain water of crystallization.

Some substances give up or lose their water of crystallization by simple exposure to air. Such substances are called “Efflorescent Substances” and a good example of this class of substance is sodium sulphate.

On the other hand, certain substances on exposure to the air take up water from the air and in some cases dissolve in this water to form a liquid. Substances of this class are called “Deliquescent Substances,” and a good example of this class of substances is calcium chloride.

**EXPERIMENT 62. Formation of crystals (rock candy)**

Dissolve as much sugar as possible in a test tube half full of boiling water.

Suspend a thread or string in this solution by hanging a small weight on the end of it and allow the contents of the tube to cool slowly undisturbed (Figure 10).

After a time the sugar will appear in large crystals upon the string which is hung in the test tube.

Large crystals of many compounds can be formed in this manner, or by allowing a solution to cool slowly in a crystallizing dish. Slow cooling is essential if good crystalline development is desired.

**EXPERIMENT 63. Crystals of tartaric acid**

Prepare a saturated solution of tartaric acid in water and pour the clear liquid into a small glass. Then set aside to cool slowly, after placing a piece of cardboard over the top of the glass to avoid too rapid cooling. After the crystals have completely separated, then remove several of them and examine under your microscope.

**EXPERIMENT 64. Crystals of epsom salts**

Repeat the above experiment using epsom salts.
TESTING WATER

Absolutely pure water is never found in nature. The impurities found in water are of two classes. The inorganic, or those that come from the rocks, and the organic, or those that are formed from the decay of animal or vegetable substances.

The principal inorganic matter found in water is common salt and compounds of calcium, magnesium and iron. Waters containing such substances in solution are commonly spoken of as hard waters, or, if large amounts of mineral matter are present, as mineral waters. Some of the natural mineral waters possess valuable medicinal properties and consequently are set aside and protected for public use. Springs of this type are located in several sections of the United States. The salts occurring in hard waters do not injure the water for drinking purposes but they form insoluble compounds with soap so that we cannot wash with them.

In addition to mineral matter natural waters contain more or less organic matter in solution or held in suspension. This organic matter is not necessarily harmful but quite often this is accompanied by certain forms of micro-organisms or living bacteria which may be very injurious to life. Typhoid fever is quite often contracted from drinking water containing bacteria of this kind. Bacteria when found in drinking water is generally destroyed by adding bleaching powder or chloride of lime to the water. Chlorine gas and ozone are also used for the same purpose with good effect.

SEWAGE CONTAMINATION

Water is made unfit for drinking purposes by contamination with sewage waste. Therefore, it is very important to make bacteriological tests of drinking water occasionally to avoid the possible spreading of disease. In fact, the sewage disposal problem of today is one that is coming to the front because sewage improperly treated is a menace to public health. The unthinking citizen believes the problem of sewage disposal is solved when the toilet is flushed or the bath tub is drained. Actually, the problem may be said to commence at this point. Many cities discharge their sewage untreated into rivers, but seldom do we find any stream in sufficient volume or speedy enough flow to make such a method efficient. Sewage allowed to stand in rivers leads to unsightly appearances and very offensive odors, and such water is unfit for drinking purposes.

BACTERIA IN INDUSTRY

Many diseases like typhoid fever result from bacterial infection, but it should be emphasized here that, contrary to a popular belief, all bacteria are not harmful to man. Great prominence has been given them as causative agents in disease. Therefore, it is perfectly natural that bacteria in general would be looked upon as organisms which are harmful to man. This is not true. Taking the entire group as a whole, they are beneficial to man in that the good they do far out-weighs the harm. While we could suggest the most important processes which depend on microbial activity, the greatest single service is no doubt the part they play in nature in causing the decay of plant and animal bodies. Were it not for this process of decay, much of the supply of certain essential elements—elements which we could not do without—would remain locked up in the dead bodies of plants and animals so that what remained would not be sufficient for the growth and development of living plants and animals. Let us then bear in mind that bacteria are not, as generally supposed, undesirable and destructive, but like all other living objects, there are good ones
and bad ones, and great as is the loss of life and property and suffering for which some bacteria are responsible, the beneficial effects out-weight the harmful effects.

**HARD WATER**

When water does not lather well with soap, it is commonly known as hard water. The chief elements which are productive of water hardness are the alkali earth metals—calcium, magnesium, barium, and strontium. The most widely occurring of these is calcium, and when we are troubled with hard water we always look first for calcium contamination in some form. There are two kinds of hard water—temporary and permanent.

**EXPERIMENT 65. Temporary hardness—How to get rid of it**

If you are able to obtain some hard water in your locality, test a half test tube full of it for temporary hardness by boiling for 3 or 4 minutes over a flame. If the water after boiling becomes turbid, that is, takes on a white milky color, it possess temporary hardness.

Temporary hardness is due to the presence of calcium bicarbonate, which is formed by the action on limestone (calcium carbonate) on the carbon dioxide dissolved in rain water. This form of hardness is easily gotten rid of by boiling. The heat drives off the excess of carbon dioxide and the calcium carbonate precipitates, giving the water a turbid or milky appearance.

It is due to this precipitate that kettles and boilers become gradually covered inside with a brown deposit. In large boiler pipes the deposit is known as boiler scale and constitutes a serious problem in manufacturing plants. On a large scale slaked lime (calcium hydroxide) made by adding water to lime is used to soften water. The soluble bicarbonate is converted into the insoluble carbonate which separates out and is removed by filtering.

**EXPERIMENT 66. Permanent hardness—How to get rid of it**

Hard water due to the presence of sulphate of lime or magnesia cannot be softened by boiling, and water of this kind is known as permanent hard water.

If you are able to procure a sample of hard water in your locality, treat a half test tube full of it with 2 measures of sodium carbonate. Shake well and if a white precipitate is formed the water possesses permanent hardness. This precipitate may be calcium carbonate or magnesium carbonate or both.

Filter off this precipitate and see if the water then run through will lather with soap. This water is soft, and it is for this reason that washing soda is used in the laundry.

Some waters contain in addition to dissolved substances as impurities also suspended matter. Often times such suspended matter is so finely divided that it cannot be separated by filtration. When such is the case the suspended matter is easily removed by treatment with aluminum hydroxide, or ferric hydroxide, gelatinous precipitates, which upon settling carry down with them the finely suspended matter in the water.

**EXPERIMENT 67. Testing for odor**

Fill a test tube half full of the water to be tested, shake the tube well and then smell at the mouth of the tube. Gently heat the tube for a few seconds and smell again. Notice any increase in odor. Heating usually drives out any dissolved gases which may be in the water as impurities.

If the water has any disagreeable odor it may be contaminated with sewage of some sort.
EXPERIMENT 68. A test for color and clearness

Examine the sample of water as follows: Hold a test tube of the water in front of a white sheet of paper and notice whether the water is colored and cloudy. If the water is colored or cloudy it is contaminated with impurities.

Quite often when water is drawn from a faucet it appears a little milky. This is due to high pressure of the water in the pipes. When this is so, allow the water to stand for two or three minutes and you will notice that the water is now clear.

EXPERIMENT 69. How to test for solid matter in water

Pour one-half test tube full of the water to be tested into an ordinary tea cup and allow it to evaporate slowly down to dryness on the stove. Look for a residue or solid matter in the cup after all the water is driven off. Most waters contain small amounts of mineral salts and sometimes organic matter which are tested for in this way.

EXPERIMENT 70. How to test for acidity in water

Add a small piece of blue litmus paper to a test tube full of water. If the litmus paper turns pink the water is slightly acid.

EXPERIMENT 71. How to test for lime in water

Add 1 or 2 measures of sodium carbonate to a test tube one-half full of the water to be tested and allow to stand for 10 or 20 minutes. If the water becomes cloudy or turbid, lime is present.

EXPERIMENT 72. How to test for carbon dioxide in water

Add a few drops of clear lime water to a test tube $\frac{3}{4}$ full of the water to be tested. A white precipitate or a milky color is a test for carbon dioxide.

Lime water is made by adding 1 measure of calcium oxide to a test tube one-half full of water, shaking well and allowing any solid material to settle. The clear liquid is lime water. Common soda water such as is served at a soda fountain is simply pure water which has been saturated under pressure with carbon dioxide. When the pressure is relieved from such water the carbon dioxide bubbles out, producing what is known as effervescence.

SULPHUR

Sulphur is a very important element commercially, and plays a very significant part in the physiological processes of animal life. It is a yellowish, tasteless solid and is practically odorless. The odor commonly ascribed to sulphur is not that of sulphur itself, but is due to sulphur dioxide when sulphur undergoes oxidation. The odor of burning sulphur is due to sulphur dioxide.

In the free state sulphur occurs chiefly in volcanic regions. Large deposits are found in Italy, Sicily, China, Ireland and India. Important deposits are found in this country in Louisiana and California. In Louisiana the sulphur is melted under ground by means of superheated steam and forced out under pressure through pipes. Sulphur also occurs in many important ores as sulphides, for example, galena or lead sulphide; cinnabar or mercury sulphide; zinc blende or zinc sulphide; realgar or arsenic sulphide, and in pyrite (iron sulphide).

Sulphur is used extensively in the commercial manufacture of many substances, such as gunpowder, fireworks, matches, dyestuffs, medicinal products, or drugs and fertilizers. Without doubt the most important chemical containing sulphur, which is manufactured, is sulphuric acid. It occupies a key position in chemical industry, and is utilized in hundreds
of manufacturing operations. Sulphuric acid is consumed in enormous quantities in the commercial processes applied in the vulcanization of rubber, in the bleaching industry, and in the manufacture of disinfectants and insecticides. The great demand for insecticides by growers of fruit and truck garden products has led to the study of many materials to be used for plant protection. Today this represents an enormous industry and there is a constant search for effective chemical insecticides. Sulphuric acid is a valuable intermediate in their manufacture.

**EXPERIMENT 73. Behavior of sulphur at different temperatures**

Heat 10 measures of sulphur in a small, dry test tube. Apply the heat very slowly and notice the different changes. First, the sulphur melts to a light straw colored liquid. Pour a little of this liquid into a glass of water, and then continue the heating of the tube, and observe, second, the change of color to brownish black and the liquid becoming almost solid. On further heating, third, this solid becomes liquid again. Pour this liquid sulphur into another glass of water.

The sulphur obtained when the straw colored liquid was poured into water is called rhombic sulphur, while that formed when the dark black liquid was poured into water is called plastic sulphur or elastic sulphur. This substance becomes brittle on standing for a few days. Sulphur undergoes three distinct changes then in heating and each change corresponds to a certain temperature.

**EXPERIMENT 74. Preparation of lime—sulphur solution**

Put into a test tube $\frac{1}{3}$ full of water 1 measure of calcium oxide and 1 measure of sulphur. Heat the test tube over a flame and boil for several minutes. Notice the yellow colored solution that is formed. This solution is known as lime-sulphur solution and is used on a large scale for spraying fruit trees and destroying fungi.

The calcium oxide reacted with the sulphur to form calcium sulphide, which is soluble in the water. Filter a part of the calcium sulphide solution, and to the clear fluid add vinegar until the solution is acid to litmus paper. There will be an immediate evolution of hydrogen sulphide, which is evidenced by the odor. Allow 1 or 2 drops of the calcium sulphide solution to fall on a polished silver coin, and let stand for a few minutes. Then wash the coin with water and notice that a black spot of silver sulphide is formed. Exposure of silverware to eggs will produce a similar discoloration due to the presence of sulphur in eggs.

**EXPERIMENT 75. Sulphur dioxide from burning sulphur**

Put 2 measures of sulphur in the spoon and heat over the flame. The sulphur will suddenly take fire and burn with a blue flame. The gas produced, having a suffocating odor, is sulphur dioxide, and is formed by the oxidation of sulphur when it burns in the air.

**EXPERIMENT 76. Preparation of sulphuric acid**

Mix together on a piece of paper $\frac{1}{2}$ measure of sulphur and $\frac{1}{2}$ measure of potassium nitrate. Put $\frac{1}{4}$ of this mixture—no more—in a clean, dry test tube and heat slowly over a flame. Notice the white fumes which are given off. These fumes are sulphur trioxide. After the fumes stop coming off, stop the heating and place the thumb over the mouth of the tube.

After the tube has become cold, fill the test tube $\frac{1}{2}$ full of water and shake the test tube, holding the thumb over the mouth. Test the liquid with blue litmus paper and notice that it turns red. Sulphur trioxide combined with the water to form sulphuric acid.
HYDROGEN SULPHIDE

Hydrogen sulphide (H₂S) and water (H₂O) are members of the same chemical family. Water is a neutral substance, while hydrogen sulphide is a weak acid. The salts of hydrogen sulphide are called sulphides. Some sulphides are very insoluble in water and for that reason find application by chemists in analytical work. Certain metals can be separated from each other by means of their sulphides.

EXPERIMENT 77. How to make hydrogen sulphide

Cut a piece of paraffin from a candle or a piece of paraffin wax about the size of a pea and put it in a test tube. Add 2 measures of sulphur, place a piece of moistened sulphide test paper over the mouth of the tube and heat the tube slowly. Notice that the test paper turns black. This is a test for hydrogen sulphide gas. The test paper contains lead acetate and when the hydrogen sulphide comes in contact with it, it forms a black precipitate of lead sulphide.

Remove the tube from the flame and smell cautiously at the mouth of the tube. Note the resemblance of the odor to that of rotten eggs. As a matter of fact this is the gas produced when eggs go bad. Hydrogen sulphide is given off from several organic compounds, for example, when cabbage is cooked.

Hydrogen sulphide is inflammable and when burned the hydrogen combines with oxygen to form water while the sulphur combines with oxygen to form sulphur dioxide.

EXPERIMENT 78. Silver sulphide

Place 1/2 measure of sulphur on a bright silver coin and wrap in several thicknesses of paper. After a few days you will find a black spot of silver sulphide on the coin where the sulphur was in contact with it.

EXPERIMENT 79. Sulphur in rubber

Rubber contains sulphur used in its vulcanization. Wrap a rubber band around a silver coin and you will find that it will turn black after a few days, due to the formation of silver sulphide.

EXPERIMENT 80. Sulphur and silver coin

A silver coin is turned black in a few hours by a paste of mustard and water, as mustard contains sulphur. Eggs also contain sulphur, and this is the reason why silver spoons turn black when used for eating eggs.

EXPERIMENT 81. Zinc sulphide

Place 2 measures of sodium bisulphate and a small piece of zinc metal in a test tube and fill the tube 1/4 full of water. Heat the tube gently and wait until some of the zinc has dissolved. Now pour some of the clear solution into another test tube, add water to fill the tube one-half full and pass in hydrogen sulphide gas.

THE HALOGENS

The elements that go to make up the halogen family are fluorine, chlorine, bromine and iodine. These elements are called Halogens, meaning salt producers. They all resemble each other very much in chemical properties but differ widely in physical properties. Fluorine is a colorless gas, chlorine a greenish yellow gas, bromine a brownish-red liquid and iodine a purplish black solid.
The halogens are very active substances, so that they never occur in the free state in nature. Their compounds are very abundant—those of chlorine, bromine and iodine occurring in sea water. The most common of these is sodium chloride or common table salt.

As already stated, the halogens are very active substances. They combine with metals like copper, sodium, potassium, gold, silver, platinum, etc., to form salts of these metals. They also react with non-metals like sulphur, antimony and arsenic to form compounds with these substances. They also react with hydrogen to form the corresponding acids, namely, hydrofluoric, hydrochloric, hydrobromic and hydriodic acids. Of the halogens, fluorine is the most active and iodine the least active. All four of the halogens find wide commercial applications.

Chlorine is used extensively as a bleaching agent and germicide. Chlorine gas is shipped in bulk compressed in iron cylinders. The gas is widely used for water purification. It also comes on the market known as bleaching powder or chloride of lime. The corresponding acid, hydrochloric acid, is an important technical acid and is used for a number of purposes.

Bromine is used particularly in the preparation of bromides, which are used to a considerable extent in photograph and in medicine. It is also used in the preparation of a number of organic drugs and dyestuffs. Bromine is extracted today in large quantities from sea water and apparently this source is inexhaustible.

The chief sources of iodine are brine wells and the ashes of certain sea weeds. Iodine is used extensively in medicine, especially in the form of tincture of iodine. It also finds an important use in the preparation of iodides and of certain dyes and drugs. The antiseptic iodoform is a compound of iodine with carbon and hydrogen. This iodine compound is analogous to the widely used anesthetic—chloroform—which is a compound of chlorine combined with hydrogen and carbon. While iodoform and chloroform are valuable drugs, the corresponding compounds of bromine and fluorine are unimportant compounds in medicine.

**EXPERIMENT 82. How to make chlorine gas**

Put two measures of potassium nitrate, two measures of sodium bisulphate and two measures of sodium chloride (common table salt) in a test tube and heat the test tube gently over a flame for a few moments. Remove the test tube from the flame and smell cautiously the gas which is given off. This is chlorine gas.

Sodium bisulphate reacted with sodium chloride to form hydrogen chloride gas which was oxidized by oxygen from the potassium nitrate to water and chlorine gas.

**EXPERIMENT 83. To show the bleaching properties of chlorine**

Prepare chlorine gas as in the preceding experiment, placing a small piece of moistened blue litmus paper over the mouth of the tube before heating. Notice on heating that the blue litmus paper turns white, showing that chlorine gas has the property of bleaching certain colors.

What happened was that the chlorine gas reacted with the water on the blue litmus paper, forming hydrochloric acid and oxygen. It is really this free oxygen that does the bleaching.

**EXPERIMENT 84. How to make hydrochloric acid**

Put two measures of ammonium chloride and two measures of sodium bisulphate in a test tube. Moisten a piece of blue litmus paper and place it over the mouth of the test tube. Now heat the tube slowly over a flame for a few minutes. Notice that the litmus paper
turns red, proving that an acid has been formed. Remove the test tube from the flame and smell cautiously the gas that is given off. This is hydrogen chloride gas.

Dip the glass rod in a little household ammonia and hold the rod over the mouth of the test tube. Notice the white fumes that are formed. These fumes are ammonium chloride fumes.

Hydrogen chloride gas, as prepared in this experiment, when dissolved in water forms hydrochloric or muriatic acid. Commercially, hydrochloric acid is manufactured by heating sodium chloride with sulphur acid.

**GAS WARFARE**

It was not until the last World War that poisonous gases were demonstrated to be an important factor in modern military science. They were introduced so unexpectedly during the critical period of the world’s conflict that the unprepared combatants were greatly handicapped in military efficiency, and months of intensive training in the new technique of chemical warfare became necessary before the different countries engaged were able to provide a defense against this new method of attack. In the early development of this new method of warfare, chlorine gas or compounds containing this halogen were used extensively, and they made up the bulk of the so-called poisonous gases. Chlorine itself is a heavy suffocating gas which can be produced cheaply, and is easily transported in steel cylinders. Other chlorine compounds of high toxicity which were used in quantity as poisonous gases were chloropicrin and phosgene. Chlorine gas was later abandoned and was replaced by special compounds containing this element in combination with sulphur, carbon and hydrogen, which proved to be more destructive and efficient for offensive military movements. One of the most valuable products developed for the chemical warfare service was a chlorine compound known as “mustard gas.” Large chemical plants were operated in the United States during the World War for the manufacture of chlorine gas, phosgene, chloropicrin, and mustard gas, to be shipped abroad to the military forces engaged in this destructive war.

Today poisonous gases fulfill an important commercial service in their uses as protective measures against bank robberies, and for police equipment in controlling public riots and serious labor strikes. Such cases provide a more effective and human weapon of defense than the rifle or police gun.

**THE GAS MASK**

As a preventative from gas poisoning, the well-known gas mask was invented. This consisted of a face piece to shut out the gases from the nose, mouth and eyes and from which ran a flexible rubber tube to a cannister or container which held the chemicals for neutralizing the poisonous gases. On breathing in, the poisonous air passes into the cannister where the deadly
gases are removed, allowing the good air to pass up through the flexible tube, the end of which is held in the mouth, and then into the lungs.

The exhaled air is passed out through a rubber slit in the lower part of the face piece. The chemicals used to remove the gases were principally a mixture of charcoal and soda lime.

**SILICATES**

**EXPERIMENT 85. Silicic acid**

Put \( \frac{1}{2} \) inch of water glass in a test tube and add water until the tube is one-quarter full. Shake to mix the liquids.

In another test tube put four measures of sodium bisulphate and fill the tube one third full of water. Shake until the solid is completely dissolved.

Pour the sodium bisulphate solution into the water glass. A jelly-like precipitate will form, and in a few minutes all the liquid in the tube will become solid.

**EXPERIMENT 86. Sodium silicate (water glass)**

Paint a thin film of water glass on a sheet of paper and let it dry for 15 or 20 minutes. Note the smooth transparent glass-like film which results.

Paste together two sheets of paper or two blocks of wood, using water glass as the adhesive. You will find that it makes an exceptionally strong paste and it is often used for this purpose.

**EXPERIMENT 87. Zinc silicate**

Place a small piece of zinc metal and two measures of sodium bisulphate in a test tube. Fill the tube half full of water, heat the solution for a moment and wait until some of the zinc dissolves. Now hold the tube in a glass of cold water for a moment or two until it becomes cool.

Add to the solution of zinc sulphate thus formed two or three drops of water glass. Zinc silicate will be formed.

**EXPERIMENT 88. Ferric silicate**

Dissolve two measures of ferric ammonium sulphate in a test tube half full of water and add two or three drops of water glass. A very pretty reddish brown precipitate of ferric silicate will be formed.

**EXPERIMENT 89. Tin silicate**

Put one measure of sodium bisulphate, one measure of ammonium chloride, and a small piece of tin metal into a test tube. Add five or six drops of water and heat the liquid, allowing it to boil for two or three minutes. Pour the clear solution into another clean test tube and add water until the tube is one-quarter full.

Now add two or three drops of water glass and in a few moments a thick white precipitate of tin silicate will form.
PART III
Organic Chemistry and Its Commercial Application to the Industries

CARBON

Organic chemistry is based on our knowledge of the properties and reactions of compounds of the element, carbon. This element is found in nature in the free condition in several forms. The diamond is practically pure carbon, while ordinary coal and graphite contain small percentages of other substances besides carbon as mineral matter. Naturally occurring compounds of carbon are of wide occurrence in nature and are found in the form of gases, liquids or oils and solids. Carbon dioxide is the most familiar gaseous compound of carbon. Manufactured illuminating gas, natural gases from wells and petroleum are all composed chiefly of organic compounds of carbon and hydrogen.

The carbonates, especially calcium carbonate, constitute a very large proportion of the natural rocks and some form of mineral carbonate are found in most localities. The building stone—marble—is a very pure form of calcium carbonate. Carbon constitutes a large percentage of all living organisms, both plant and animal, and is represented in such organic products as proteins, fats, sugars and natural oils. All products of these types are widely utilized by man as food and for the manufacture of useful commercial products. At the present time more than 300,000 organic compounds are known, and the possibilities of new creations as the science of organic chemistry is developed are unlimited. Of all the elements occurring in nature, carbon is the one which is most commonly associated with life itself. Our present world could not exist without this element.

Coke is a modified form of impure carbon, and is used as a fuel in operating steam boilers, and also in smelting processes for refining ores. It is made by heating bituminous, or, as it is more commonly known, soft coal until all volatile products in the coal have been expelled. This heating process is conducted without excess of air, and is carried out on a commercial scale in large ovens. The volatile or gaseous products are refined and constitute the raw materials for the manufacture of illuminating gas and low boiling hydrocarbons like benzene.

Every boy and girl is familiar with ordinary charcoal. This is a form of carbon produced by the destructive distillation of organic substances such as wood and sugar, and even bones of animals. By destructive distillation is meant heating without access to air as in the manufacture of illuminating gas. The quality of wood charcoal obtained is dependent on the kind of wood which is subjected to destructive distillation. It is known, for example, that the destructive distillation of cocoanut shells is productive of a very efficient form of absorbent carbon meeting the exacting requirements of the gas mask. If air was admitted during the distillation process, the charcoal and gaseous products would be burned up completely with formation of carbon dioxide gas and water.

Another form of carbon is graphite. This is the black substance which forms the core of lead pencils. It is sometimes referred to as lead, but this is not correct. It is not lead, but a modified form of carbon, and can be made by subjecting carbon to a very intense heat. At about 4000° C. carbon vaporizes, and this vapor on condensing forms graphite. Graphite is
used in the manufacture of crucibles, as a lubricant, as a protective covering for metals such as stove polish, and in the manufacture of lead pencils.

Lamp black, an amorphous form of carbon, finds wide application in the trades. It is used in rubber as a toughening agent; in printers’ ink as a pigment; in paints, stove polishes and lacquers as a pigment; on typewriter ribbons and carbon papers as a black coloring matter. Boneblack is an amorphous carbon produced by destructive distillation of bones. It is used as a deodorizing and decolorizing agent.

**EXPERIMENT 90. Preparation of charcoal—pyro-ligneous acid**

Break up a few toothpicks or pieces of wood and place them in the bottom of a test tube. Now put a piece of moistened blue litmus paper over the mouth of the test tube and heat over an alcohol lamp or gas flame. Notice that the paper turns red, proving that an acid is evolved. This acid is called pyro-ligneous acid and is essentially acetic acid. Acetic acid is also present in vinegar. Here it is formed in the process of fermentation resulting by the action of bacteria on sugar.

Now insert the perforated cork with delivery tube, continue heating and light the gas that comes off. Notice that it will burn. This gas is similar to that obtained from the distillation of coal.

When no more gas is evolved, allow the tube to cool, then empty the contents of the test tube on paper. This is charcoal and is practically pure carbon.

When green pine (or green cedar wood) is distilled, turpentine and tar oils are derived from it. The turpentine is the volatile oil, that is, it passes off as a vapor. The tar oils are the heavy resinous oils, brown in color, such as you may see at the bottom of your test tube.

To summarize, when coal is heated without admission of air, coal gas, ammonia and coal tar are obtained. The gas is used for lighting and heating. The ammonia which is derived is purified and finds many uses. From the coal tar are derived intermediates from which aniline dyes, disinfectants such as carbolic acid, high explosives and many other valuable products are manufactured.

It can be seen, therefore, that enormous industries are based upon this process of heating wood and especially coal without admission of air.

**ABSORBENT CHARCOAL**

**EXPERIMENT 91. Decolorizing vinegar**

Fill a test tube one-quarter full of vinegar which has a brownish or yellow color. Add two measures of charcoal and shake with the solution for four or five minutes. Now separate the charcoal by filtering, and you will find that the color of the vinegar is lighter. The vinegar can be made almost colorless by repeating this several times.

**EXPERIMENT 92. Absorbing bitter taste with charcoal**

If you can obtain a small amount of quinine you will find that charcoal will absorb the bitter taste. Fill a test tube one-quarter full of water and add a very small amount of quinine, about the size of an ordinary pinhead. Shake this with the water and taste a drop of the solution and notice the bitter taste.

**EXPERIMENT 93. Absorbent charcoal from ground cocoanut shells**

Grind up a piece of dry cocoanut shell and thoroughly bake the material in a copper oven. This should be thoroughly carbonized by this treatment. After baking then grind the
particles of dried shell to a powder by rubbing in a mortar. Test the efficiency of this powder as a decolorizing and absorbing agent.

**EXPERIMENT 94. Absorbent charcoal from butternut shells**

Crack some butternuts and eat the meat of the nuts. Then take the shells and thoroughly crush them and finally carbonize by heating in a copper oven. After this baking, then grind to a powder in a mortar. Test the efficiency of this powder as a decolorizing agent and absorbing agent.

**EXPERIMENT 95. Surface tension and the rubber band**

Float a thin rubber band on a dish of water and touch the water inside the band with a wire or toothpick which has been dipped into oil. The band will snap out, forming a circle. Now apply oil to the water outside of the band and the band will again resume its original shape.

This experiment illustrates the effect of surface tension which tends to make liquids assume those forms which expose the least surface for a given volume.

**EXPERIMENT 96. Changing the specific gravity of charcoal**

Wood charcoal floats in water. Tie a weight on a piece of charcoal with a thread so that it will sink and place it in a test tube one-quarter full of water. Boil the water for several minutes, then remove the weight from the charcoal, and you will find that it no longer floats. This is due to the fact that the air was driven away from the pores of the charcoal by boiling. This experiment illustrates why wood becomes waterlogged and does not float.

**CARBON MONOXIDE**

While carbon dioxide is a harmless gas, this member of the carbon family is a violent poison. It is formed when carbon is burned with a diminished supply of oxygen. The gas burns with a blue flame, being converted into carbon dioxide.

Several thousand people are killed each year by carbon monoxide gas, which constitutes a small proportion of the gases expelled through the exhaust pipe of an automobile.

With the return of cold weather, the specter of carbon monoxide poisoning haunts every automobile driver. Unless humanity has exercised an excess of caution, we may expect occasional news items about persons warming up their motors in closed garages, being overcome by this insidious gas. Carbon monoxide is a product of imperfect combustion.

When a fuel is burned under perfect conditions, carbon monoxide is not produced. The products of perfect combustion are carbon dioxide and water. Ideal combustion conditions are difficult to realize. Certainly not in the very best of our automobiles. An analysis of the exhaust gases of an average automobile shows about 7% of carbon monoxide. In a certain experiment a dog was left in the driver’s seat of an automobile in a closed garage, with the engine running slowly. In twenty minutes the dog was unconscious. Had a man been in the dog’s place, the result would probably have been the same. Carbon monoxide overcomes its victim with no warning. The first symptom is a severe pain in the back of the head, but if the concentration is high, the victim may lose consciousness before he can act on this warning. This condition may or may not be preceded by such warnings as headache, dizziness or nausea. Small doses may have no other effect than to cause severe headache, but a heavy gassing is a serious matter. Convalescents from carbon monoxide poisoning should be kept in bed even when they protest that they are all right. To avoid carbon monoxide poisoning it needs no more than good ventilation in the garage. Carbon monoxide is lighter than air, and vanishes immediately through an open window or door. A doctor
should be called immediately for a person overcome by the gas. An automobile driven by a
driver under the influence of carbon monoxide gas constitutes a hazard to the public safety
on the highway equal in seriousness to that of another car equipped with faulty brakes. It
has been found that an automobile, following too closely behind another, particularly in
heavy traffic, may pick up a sufficient quantity of the exhaust gas from the preceding car to
result in a dangerous mixture within the second automobile, leading to carbon monoxide
poisoning.

**ETHYL GAS**

Every automobile driver is familiar today with the trade term—“ethyl gas.” This is an
organic compound containing lead which bestows on gasoline the favorable properties
characteristic of this reagent (tetraethyl lead). It is a practical anti-knock substance. When
ethyl gasoline is used, it tones down the explosions in the cylinders of gas engines, and
pushes the cylinder more gently than in the case when ordinary gasoline is used. Tetraethyl
lead is a dangerous substance, and warnings, therefore, accompany its use. At every filling
station there are warnings posted to the effect that ethyl gas should not be spilled upon the
hands or used for cleaning purposes. If ordinary precautions are followed, tetraethyl
gasoline presents little danger during use.

**EXPERIMENT 97. Vinegar and baking soda**

Obtain some very strong cider vinegar, the stronger the better, and place about 15 drops
in a test tube. Then drop into the vinegar a small measure of baking soda. What gas is
given off? Test for it.

**EXPERIMENT 98. Vinegar and oyster shells**

Repeat the above experiment using a piece of oyster shell. Pulverize the shell in a mortar
before adding it to the vinegar. Warm the solution and test the gas given off.

**EXPERIMENT 99. Vinegar and painter’s whiting**

Repeat the above experiment using some painter’s whiting. What is the composition of
ordinary whiting?

**EXPERIMENT 100. Vinegar and chalk**

Repeat the above experiment using some powdered chalk or crayon from your school
room blackboard.

**EXPERIMENT 101. Vinegar and marble**

Repeat the above experiment with some pulverized marble.

**EXPERIMENT 102. Vinegar and tooth powder**

Repeat the above experiment with a good quality of dental tooth powder. What constit-
uent of tooth powder causes the reaction?

**EXPERIMENT 103. Vinegar and old mortar**

Repeat the above experiment using some old mortar removed from the walls of an old
brick building. Note the evolution of carbonic acid gas.

**EXPERIMENT 104. Vinegar and Portland cement**

Repeat the above experiment using some pure Portland cement.
EXPERIMENT 105. Carbon dioxide is heavier than air, and will not burn

Light a candle and set it firmly on a board by sticking it to a little melted wax from the flame of the candle. (Figure 12.)

Now put one-half teaspoonful of sodium bicarbonate or common baking soda in a glass and add some vinegar or a solution of tartaric acid to the glass. A violent reaction takes place with evolution of carbon dioxide gas. Now pour the gas in the glass on to the flame just as though you were pouring water out of the glass, taking care not to spill any of the acid out of the glass. Notice that the flame goes out, proving that carbon dioxide is heavier than air and will settle to the earth and also that it will not burn.

EXPERIMENT 106. Chemistry of the flame

Examine closely an alcohol lamp flame or candle flame and observe that it consists essentially of three cones. (Figure 13.) First a dark cone just around the wick; second, a yellow cone which produces light; and third, a semi-transparent cone of heat around the outside.

The dark cone of the flame consists of unburned gases which are given off from the wick of the candle. The paraffin is melted by the heat and drawn into the wick by capillary action. In the wick the paraffin is converted into a gas by the heat of the flame. To prove this, hold one end of a hollow glass tube in the flame just over the wick. Now apply a flame to the other end of the tube and it takes fire. The gas in this cone is relatively cool, for if a match stick is placed in it that portion of the stick which was in the dark cone will not burn as soon

FIG. 12

FIG. 13
as the portion passing through the sides of the flame.

The second or yellow cone of the flame consists of particles of carbon that have been heated to white heat so that they glow brightly.

Hold a cold spoon or glass rod in this cone for a minute and notice that it is covered with a black deposit of carbon called lampblack, thus proving that this cone consists of small particles of carbon. The cold spoon chilled the flame, thereby causing the carbon particles to be deposited. Lampblack is made upon this principle on a manufacturing scale.

The third or outer cone of the flame consists of the gases formed by the complete burning of the carbon particles to carbon dioxide gas. This is the hottest portion of the flame, and whenever heating a liquid in a test tube, for example, it is important, in order to obtain the highest heat possible and to prevent the deposit of soot, to hold the test tube at the tip of the luminous or light-giving part of the flame.

**EXPERIMENT 107. Carbon dioxide from a burning candle**

Make some lime water by putting two measures of calcium oxide in a test tube half full of water and shaking well for three or four minutes. Allow this solution to stand until clear, then pour the clear liquid into another test tube. You now have a clear solution of lime water or calcium hydroxide.
Now hold a wide mouthed bottle or fruit jar over a candle flame as shown in Figure 14 so that the burning gases from the flame may enter the mouth of the bottle. After allowing the gases to enter the bottle for about a minute, close the mouth of the bottle with the palm of the hand, and, inverting the bottle, pour the lime water into it. Again put the palm over the mouth of the bottle and shake for a moment. Notice that the lime water becomes turbid or milky. This turbidity is due to a white precipitate or calcium carbonate formed by the action of carbon dioxide on calcium hydroxide.

EXPERIMENT 108. The structure of a flame—A gas factory

If you will look closely at a candle flame you will see that it consists of three parts. First, a dark zone just around the wick. Second, a bright yellow zone which gives the light. Third, a transparent zone of heat around the outside.

The first or inner zone consists of unburned gas given off from the wick of the candle. The melted grease is drawn up by a capillary action into the wick and is there converted into gas by the heat of the flame. With care a portion of this gas can be drawn off through a tube.

Hold one end of the glass tube in the flame and directly over the wick. Hold the tube slanting upwards so that the other end is out at the side and a little above the flame. If held correctly smoke will come from the end of the tube and can be lighted with a match.

That it is relatively cool inside of the flame can be shown by thrusting a match stick into this zone for a few seconds. The portion of the stick which was held in the dark zone will not be burned as soon as that portion passing through the sides of the flame.

EXPERIMENT 109. The structure of flame—Manufacturing lampblack

The second or bright yellow zone of the flame contains particles of carbon heated to a white heat so that they glow brightly. The carbon is formed by the action of the heat on the gas of the inner zone.

The presence of this carbon can be shown by holding a cold spoon or piece of glass tubing in the flame for about a minute. You will notice that when you take it out it is covered with a black deposit of lampblack or soot which is one form of carbon. The cold spoon chills the flame and prevents the carbon from being completely burned.

Lampblack is made on a large scale in just this way except that natural gas is burned instead of candles and the cooling is done by means of iron pipes with water circulating through them.

The third or outside zone of the flame consists of the gases formed by the complete burning of the carbon particles. If you will hold the cold spoon in the outer zone you will find that it gets very hot but that no soot or only a very small amount will be deposited. This zone is above the luminous one.
EXPERIMENT 110. Carbon dioxide in the breath

Make up a solution of lime water as previously directed.

Now take a hollow tube, put one end into the test tube containing the lime water and allow your breath to bubble through the lime water. (Figure 15.) Notice that very soon the water becomes turbid and after a short while a white precipitate is formed. This precipitate is calcium carbonate and is formed by the action of carbon dioxide in the breath upon lime water or calcium hydroxide.

TANNIN AND ITS APPLICATIONS

The raw skin obtained from an animal must be chemically treated to become useful as leather or fur, otherwise it comes shrivelled and horny when dry, or, if wet, it is attacked by bacteria which causes putrefaction and decay.

The chemical treatment is called tanning, and the chemical which combines with the raw skin to change it to leather is called a tannin.

There are many tannins from different sources which are alike only in their ability to convert raw skin into leather. Simple treatment with salts like alum and with oils may suffice for furs. Chromium compounds are used in chrome tannage, and complex compounds produced by the action of formaldehyde and sulphuric acid on phenols are known as synthetic tannins or “syntans” but have their use limited by cost. The principal tannins are extracted from trees and plants, sometimes from the bark, sometimes from wood, leaves, or fruit. The bark of oak and hemlock and the wood of the chestnut tree have long been used, but one of our most important sources of tannin is now the wood of the quebracho tree which grows in South America. Your chemical set contains a supply of purified tannin called tannic acid.

Tannin is unpleasant to taste for it puckers the mouth, as anyone knows who has tasted a green persimmon. If you follow the directions given below you can easily test various plant materials to see if they contain tannin. Possibly you may discover a valuable new source of tannin in some ordinary weed.

The tanning of skins to make leather is too long a process to describe here but there are many other applications of tannin which make interesting experiments.
EXPERIMENT 111. Testing for tannin

Measure out one spoonful of ordinary gelatin such as is used in the kitchen for making desserts. Also measure out seven spoonfuls of sodium chloride (common salt) and dissolve them together in ten test tubes full of water. This is your test solution. It spoils quickly, just as moist raw skins do unless you add a drop or two of a suitable antiseptic such as carbolic acid.

EXPERIMENT 112. Test for tannin in tea

Drop a pinch of dry tea in a test tube, cover it with water, and heat nearly to boiling. Now carefully pour off the clear tea extract from the leaves and add a drop or two to a little of the gelatin test solution. Also add a drop or two of ferric alum solution to some of the tea extract in another test tube. Do you find any tannin in tea?

EXPERIMENT 113. Tannin from oak bark

Obtain some oak bark and cut it up into fine shavings. Put some of these shavings in a test tube half full of water and boil for two or three minutes. Allow the test tube to cool and pour the liquid into another test tube. Test as above for tannin in the extract.

EXPERIMENT 114. Tannin from hemlock bark

Using hemlock bark, follow the above instructions.

EXPERIMENT 115. Tannin from chestnut bark

Using chestnut bark, follow the directions for oak bark.

EXPERIMENT 116. Tannin from chestnut wood

Using chestnut wood, follow the directions for oak bark.

EXPERIMENT 117. Tannin from sumac leaves

Using sumac leaves, follow the directions for oak bark.

EXPERIMENT 118. Tannin from acorns

Using acorns, follow the directions for oak bark.
Try testing many other common trees and plants for tannin.

HOME KITCHEN CHEMISTRY

EXPERIMENT 119. The use and care of aluminum ware

Obtain an old aluminum pan and put some vinegar in it. Warm slightly and notice the corrosive action which the vinegar has on aluminum. Add a small quantity of salt to the vinegar and notice that the corrosive action is increased. Put a small quantity of lye in the aluminum pan, dissolve it in water, and notice that this also corrodes the aluminum.

This experiment shows that acids and alkalies should not be put in aluminum ware for cleaning or polishing. Neither should acid foods be prepared or kept in aluminum vessels. Salad dressing containing vinegar and salt, for example, would corrode aluminum pans very badly and also introduce aluminum compounds into the food.

EXPERIMENT 120. Why zinc vessels are not used for foods

Test the solubility of zinc in acids, for example, warm vinegar. Also test the solubility of zinc in a strong lye solution. You will see that zinc is attacked by acids and alkalies; therefore, foods should not be kept or prepared in zinc vessels. Sodium chloride solution also attacks zinc readily, and as the soluble compounds of zinc are poisonous, it would be very dangerous to use zinc vessels in preparing foods.
EXPERIMENT 121. Cooking in copper vessels

Test a strip of copper in acids; for example, two measures of sodium bisulphate in a test tube one-quarter full of water, strong vinegar, etc. Notice that especially when the solution is heated the copper dissolves in the acids. Add a few drops of household ammonia to an acid solution which has acted on copper. We find, therefore, that copper vessels are not good for cooking foods as the copper will dissolve in acids and the soluble salts of copper are poisonous.

EXPERIMENT 122. Testing silver plate

To find out whether an article is plated with nickel or with silver prepare a solution of four measures of sodium bisulphate in a test tube half full of water. Put the article which you wish to test in this solution and warm it for a few minutes. If a greenish solution is formed, the article contains nickel. Test the solution by adding sodium carbonate until it no longer effervesces and then generate hydrogen sulphide gas, and pass the gas through your delivery tube into the solution. A black precipitate indicates nickel.

EXPERIMENT 123. A test for soil in the flower pot

Remove a sample of soil from your mother’s flower pot and mix with sufficient clear water to make a thin paste. Insert a strip of blue litmus paper in the mixture and allow it to remain for half an hour. Withdraw the paper and wash with water. If the paper has turned pink the soil is acid.

EXPERIMENT 124. A fragrant paste wax

One part of carnauba wax and one part of bayberry wax are mixed with sufficient turpentine to form a thick paste. Be sure to mix thoroughly in order to obtain a uniform paste. Apply this mixture to a piece of furniture that your mother would like renovated. Rub briskly when dry to obtain a good polish.

EXPERIMENT 125. Making soap

Make a solution of caustic soda or lye by putting three measures of sodium carbonate and four measures of calcium oxide into a test tube half full of water and boil for two or three minutes. Allow the tube to cool and when the liquid has settled pour the clear liquid into another test tube. Now add a piece of lard or butter about the size of a marble and boil the liquid again for a few minutes, being careful that the liquid does not bump out of the test tube. You can prevent this by shaking the tube in the flame while heating. Notice that the lard or butter dissolves very readily in the hot alkali. Now add three measures of common salt and heat the mixture again for two or three minutes. Allow the contents of the tube to cool and notice that the soap separates out as the upper layer. The liquid layer below contains glycerine, salt and impurities. Try washing your hands with the soap you have made.

EXPERIMENT 126. Perfumed soap

Put a heaping spoonful of soap shavings into a dish and add four or five drops of a selected perfume. Grind the mixture up thoroughly and then form it into a cake by pressing it into a smooth mould. Various perfumes can be used to make soap any odor desired.

EXPERIMENT 127. Liquid soap

Put a spoonful of soap shavings into a glass and add water, a few drops at a time, stirring the mixture continually. When the proper consistency has been reached pour the liquid soap into a bottle if you wish to keep it.
EXPERIMENT 128. Laundry soap

Put three or four measures of soap shavings in a mortar and grind it to a paste with four or five drops of water glass. When you have a good mixture scrape it in a pile on a plate or tin pan and let it dry. Laundry soap frequently contains water glass or sodium silicate as well as sodium carbonate.

EXPERIMENT 129. How biscuits are raised

Put a teaspoonful of flour in a tumbler and add four measures of sodium bicarbonate. Stir this mixture with a little water until you have a dough like bread dough. Now put a piece of this dough about the size of a marble on your spoon and heat it over an alcohol lamp flame. Notice that the dough swells and that it becomes porous or light, due to the gas that is formed in it.

Ordinary baking soda is sodium bicarbonate; when treated it gives off part of the carbon dioxide gas which it contains, so when used in biscuits, cakes, etc., the gas coming off raises the dough and makes it porous. In cooking, sour milk, or other acid, is used with the baking soda. This neutralizes the soda and gives off more carbon dioxide gas.

EXPERIMENT 130. Protein in the white of an egg

Place in a test tube some white of a boiled egg and mix well with one measure of pulverized calcium oxide. Then add three or four drops of water and heat the mixture over an alcohol lamp and smell the gas that is generated. Conduct some of the gas evolved over a moistened red litmus paper. Proteins contain nitrogen. Egg white is a protein substance and on heating with calcium oxide is decomposed with liberation of ammonia.

EXPERIMENT 131. Protein in a piece of silk

Repeat experiment 130 using a piece of rayon silk.

EXPERIMENT 132. Testing canned goods for copper

This test may be applied on a great variety of food articles such as canned peas, beans, ordinary spinach, apricots, pears, pickles, sauerkraut, etc. Grind together a selected sample of the food to be tested with two or three measures of sodium bisulphate and several spoonfuls of water. Heat this mixture for several minutes below the boiling temperature of water (212° F.) in a sauce pan and finally let stand on the back of a warm stove. Finally drop into this hot solution a polished wire nail and let it remain there for about one-half to one hour. It is well to stir the contents of the pan occasionally. If the wire nail takes on a red color due to copper plating this will be evidence that the sample of food product you have tested will contain traces of copper.

EXPERIMENT 133. How to test butter

Place a small piece of butter about the size of a pea in your spoon and heat it slowly over a flame. If the butter foams and froths on boiling the butter is fresh. On the other hand, if it sputters or pops it is either oleomargarine or renovated butter.

Another test that may be applied to butter to show whether it is adulterated is as follows: Heat a half cupful of milk until it is very hot. Then put into the milk a piece of butter about a half inch square to be tested and stir until it is all melted. Now place the cup in a pan of cold water containing a little ice and stir the milk continually until the milk becomes cold and the butter solidifies. If the butter is pure or renovated it will solidify into small particles throughout the milk. If it is oleomargarine it will solidify into one solid cake.
Pure fresh butter contains water and butter fat. Butter fat consists principally of the fats olein, palmitin and stearin. The flavor of the butter is due to the presence of a small amount of butyrin, which is an ester of butyric acid and glycerine.

Oleomargarine is made from the fat of cattle and hogs, together with small amounts of cotton seed oil and milk or butter. The milk or butter is added to furnish enough butyrin to give the butter flavor.

Renovated butter is stale or rancid butter made over by chemical treatment.

EXPERIMENT 134. How to make casein

Put three measures of sodium bisulphate in a test tube one-third full of water and shake until it dissolves. Now add a few drops at a time with constant shaking some of this solution to a half test tube full of milk. Notice that suddenly a white curdy precipitate is formed. This precipitate is casein. This is the same precipitate that is formed when milk turns sour or curdles. The souring of milk is brought about by the formation of lactic acid, due to the fermentation of the milk.

Casein besides being used as a food in cheese has many other important uses today. It is used in the manufacture of adhesives, paints, in dyeing, in medicine, as electrical insulators and in making plastic masses as in stoneware, toys, etc. In the manufacture of these things the casein is put through a certain chemical treatment.

EXPERIMENT 135. How to cement broken glass

By means of a small camel’s hair brush, paint the broken surface of the glass with water glass. After the water glass starts to harden, which will require a few minutes, press the two broken surfaces together and allow the glass to remain this way for a day or two. If on pressing the two surfaces together a little of the water glass squeezes out, rub this off with a damp cloth. Notice after a day or two that the pieces are held very firmly together. Glass mended with water glass will not hold together in contact with water, since water glass is soluble in water.

EXPERIMENT 136. A common household adhesive paste

Make a starch paste by shaking 12 measures of powdered starch in a test tube one-fourth full of water. Stir a little with a stirring rod if necessary. Now to this paste add half a test tube full of boiling water containing three measures of calcium chloride. Pour this solution into the test tube containing the starch paste and heat the contents of the test tube to boiling. Allow the test tube to cool. This gives a paste which is very good for ordinary household use, such as pasting on labels.

EXPERIMENT 137. Magic transfer solution

This solution transfers pictures to cloth, paper dishes, etc., in their original color. The solution is made as follows: common castile soap, half bar; turpentine, quarter pint; water, half gallon. Dissolve the soap in the water and then add the turpentine. To use, apply with a small brush to any printed paper or picture and then lay a clean paper or cloth over the picture and rub quite hard with the back of a spoon. To transfer to glass or to dishes use white varnish and do the same as above. You can make up a few bottles of this solution and sell some to your friends at school.

FERMENTATION

Fermentation is the decomposition or breaking down of complex organic compounds into simpler substances by certain living organisms called ferments. There are many
different kinds of fermentation depending upon the different kinds of organisms or ferments. The most familiar illustration of fermentation is the fermentation of fruits or fruit juices, the decay of vegetable matter or nitrogenous matter, the souring of cider or of milk and that taking place in bread making by action of yeast. Most organic substances, especially the complex substances, are subject to fermentation changes. The chemical changes brought about by ferments consist in the breaking down of complex molecules to form simple groups of atoms. In some cases it consists in a rearrangement of the atoms in the molecule to form a compound with different properties. There are many kinds of living organisms or ferments, each of which produces its special change. Most ferments are microscopic plants of simple structure which multiply very rapidly when placed in the proper medium or substance. They are variously known as microbes, germs and bacteria. Yeast which is used so commonly in bread making is a microscopic plant found in the air and about certain fruit trees. The yeast cakes which you buy in the store are these same living organisms which have been grown in some suitable culture medium as the potato or corn meal. The above class of ferments are known as organized ferments. The other class of ferments are called chemical or unorganized ferments and are known as enzymes. Examples of these are pepsin, trypsin and diastase.

The action of ferments on organic substances always works best at definite temperatures. Above these temperatures the ferments or organisms are destroyed or their action delayed.

**EXPERIMENT 138. Changing sugar into carbon dioxide**

Put two spoonfuls of corn syrup or molasses in a tumbler half full of water and stir it up. Then dissolve one-quarter of a cake of yeast in a small tea cup full of luke warm water. This is best done by allowing the yeast to stand in the water for about a half hour and then stirring. Now pour the solution of yeast into the tumbler containing the syrup and set the tumbler aside in a warm place for several hours. Notice that after some time a reaction is taking place, small bubbles of gas being given off.

Hold a lighted match over the surface of the liquid in the tumbler and notice that it goes out, due to the carbon dioxide gas which is given off. The syrup or molasses contains a large amount of sugar and during the fermentation produced by the yeast this sugar is changed into carbon dioxide gas.

**EXPERIMENT 139. The formation of mould**

Mould is another form of ferment. You have probably noticed the formation of mould on such substances as sour milk, vinegar and starch which have been exposed to the air for some time. These substances contain the proper food material for certain bacteria in the air. As a result these bacteria, under proper condition of heat get into these substances and multiply very rapidly, producing the mould.

Prepare a starch solution as follows: Put a half spoonful of starch in a tea cup and add one spoonful of water. Stir until the starch forms a paste with the water. Then fill the cup with boiling water and stir until the starch forms a very gelatinous paste. It may be necessary to boil this mixture in a tin cup or pan for a few minutes to form a heavy paste.

Now set the starch solution aside in a warm place for a few days and notice after some time the formation of mould on the surface of the starch.

**EXPERIMENT 140. Growth of mould**

Place one-half teaspoonful of ordinary starch in a small pan and add to this a small amount of water. Stir to form a perfect paste and then add about 10 test tubes full of boiling water. Set the pan on a stove and continue to boil until a perfect paste is formed.
This paste is now bacteria free. Finally pour the paste into an ordinary tumbler and set it away in a warm place. It will soon become infected with bacteria from the air. Examine it from time to time and notice when mould begins to form. After some mould has formed examine its appearance under a microscope.

**EXPERIMENT 141. Composition of mould**

Carefully remove some mould from the surface of the starch mixture and test it for sugar, starch, protein and ammonia.

**EXPERIMENT 142. Making vinegar**

Take about 10 test tubes full of freshly made sweet cider and add to this two or three drops of strong vinegar. Place the mixture in an ordinary tumbler and set aside, after covering with a plate or piece of cardboard to keep the dust out. At the end of each day taste a little of the cider. You will notice that it becomes more sour daily, and that finally it will have become unfit for drinking and has turned into vinegar. This is a well-known case of fermentation brought about by means of a bacterial organism. The sweetness of the original cider is due to the presence of sugar. By the prolonged action of a special low form of organic life the sugar is transformed into acetic acid. Test your original cider and the final fermented product with a blue litmus paper.

**EXPERIMENT 143. Souring of milk**

Take a tumbler of sweet milk and set it in a warm place where you can watch it. Observe the changes that take place day by day. The milk will become infected with bacteria and undergo fermentation with formation of lactic acid. This organic acid is formed from the milk sugar in the fresh milk. The lactic acid causes the milk to curdle.

**TEXTILE CHEMISTRY AND DYEING**

Textile fibers may be grouped in two classes according to their source: vegetable fibers and animal fibers. Cotton, linen, and rayon are all of vegetable origin, the first two being the natural fibers as gotten from the cotton and flax plants, respectively, while rayon is a very interesting textile material produced by first dissolving the cotton substance, called cellulose, and then from the viscous liquid spinning a thin filament which is hardened chemically into a thread so fine and lustrous that it was originally called artificial silk. But since its chemical and physical properties were in many ways unlike true silk, it was soon given a name of its own, rayon. Cellulose is a common material in the woody structure of all plants and trees, so it is not necessary to destroy good cotton fiber to make rayon. It is of further interest that the solubilized cellulose enters the composition of many of our lacquers, and also that, if formed into a sheet instead of fine thread it becomes the well-known cellophane.

Silk and wool are produced by animals, the first being the cocoon of the silk worm, and the other, as you all know, is the warm coat of a sheep. These fibers are therefore very different from the cellulose group, and are spoken of chemically as proteins. The chemical difference between these classes of textile fibers are important to remember, especially in connection with dyeing and with spot and stain removal.

The cellulose of vegetable fibers is very easily damaged by strong acids, but is uninjured by quite severe treatment with alkali. These fibers do not combine with dyes very readily, and it is frequently necessary to deposit the dye on the fiber in a water-soluble form, then convert it to an insoluble product, in order to hold it permanently on the fiber.
Animal fibers, on the contrary, are much more resistant to acid and more easily damaged by alkali than the vegetable fibers. They combine with many dyes so firmly that the problem of dyeing colors fast to washing is greatly simplified.

Years ago most dyeing was done with the colored extracts of various plants. There were a limited number of these and many of the bright colors so common today could not be obtained.

Gradually there were discovered ways of making new dyes in the laboratory, building them up from simpler compounds obtained, in many cases, from coal tar. These dyes, sometimes called aniline dyes, now supply every hue of the rainbow and have almost completely displaced the natural dyes.

TESTING TEXTILE FIBERS

EXPERIMENT 144. The burning test

Obtain samples of several fabrics. Take a few threads from a sample and light one end in the flame of an alcohol lamp. If the sample is an animal fiber it will not burn rapidly but will char into little black knobs and will produce an odor like burning feathers or hair. If the threads burn readily, leaving a clean white ash, they are vegetable fibers. This test is particularly useful in recognizing whether a sample is silk or rayon. One type of rayon, cellulose acetate sold under the trade name “Celanese,” does not burn readily like the other rayons, but more like silk, except that it does not give an odor like burning feathers. Hence an additional test is needed if cellulose acetate is suspected of being present.

EXPERIMENT 145. Microscopic examination

With experience one can soon learn to recognize most of the fibers by appearance and feel. A magnifying glass or microscope is a great help. With it, wool is seen to have a rough scaly surface while silk is quite smooth. Rayon appears much like silk, but of course the burning test will show them different. The cotton fiber is seen to be an irregular, flattened tube.

EXPERIMENT 146. Wetting test to identify linen

Linen is more readily wet through than the other fibers. This property is made use of in the following test. Put a small piece of cloth in a test tube half full of water and add one measure of sodium bisulphate. Heat the solution to boiling. (Be sure that the sample is very small so that it does not prevent free circulation of the water.) Take out the sample, wash it several times with water and dry it. After it is dry, loosen several of the fibers with a pin or needle and moisten them with a drop or two of glycerine. Press the cloth between two blotting papers and then examine very carefully the fibers which were moistened with glycerine. If they are linen they will be semi-transparent, while other fibers will appear opaque.

EXPERIMENT 147. A quantitative test for fabric composition

The fact that caustic soda dissolves animal fibers without attacking vegetable fibers serves as a basic for one method of determining their percentage in a fabric.

Put six measures of calcium oxide and six measures of sodium carbonate in a glass containing three test tubes full of water. Boil for several minutes, then let stand to settle and pour the clear liquid, which is sodium hydroxide into a clean cup while you wash the solid residue from the glass. Return the sodium hydroxide solution to the clean glass.
Now take a sample of cloth which you suspect is made of a mixture of animal and vegetable fibers such as wool and cotton. Weigh it carefully, then immerse it in the sodium hydroxide solution and boil it for a few minutes. This should dissolve any wool or silk. Remove the remainder of the sample, rinse it in water, dry, and weigh. The loss in weight represents the wool or silk which had been in the fabric.

**DYEING**

You will find it very instructive in the following dyeing experiment if you prepare small patches of cloth containing threads of several kinds. Cut squares of white cotton, about two inches each way. Cotton from an old sheet or pillow case is better than new cloth for by many washings the fibers have become easier to dye. Next obtain coarse white threads or yarns of wool, silk, rayon, and linen. With a needle, stitch one of each of these threads across each square of cotton, using long stitches to keep most of the thread showing on one side. Trim the threads even with the edges of the patch.

**EXPERIMENT 148. Dyeing with an aniline dye**

Aniline dyes are now supplied ready for household use, and the beginner will find these very interesting to experiment with. You will undoubtedly find some on hand in the home laundry.

Dye one of your patches of cloth in one of these dyes, following the directions on the package. Are all the kinds of textile fiber in the patch dyed alike?

**EXPERIMENT 149. How to make a brown sulphur dye**

Put five drops of glycerine in a dry test tube and add one measure of sulphur and one measure of sodium carbonate. Heat the test tube over an alcohol or gas flame for several minutes and then allow the test tube to cool.

Now add a little water to the test tube and allow the test tube to stand for half an hour until the cake is loosened in the bottom of the tube. Now pour the contents of the tube into a glass of water and notice that the dye dissolves and the water is colored brown.

**EXPERIMENT 150. How to make blue horse chestnut dye**

Put several chips of the bark from a horse chestnut tree into a test tube half full of water and boil for four or five minutes. Now add a little household ammonia and boil again for two or three minutes. Notice the blue colored solution which is formed.

**EXPERIMENT 151. How to dye cotton iron buff**

Make a solution of ferric ammonia sulphate by dissolving two measures of the compound in a test tube one-third full of water. Place in this solution a small piece of cotton cloth to be dyed and shake the contents of the test tube thoroughly. Remove the cloth and allow it to dry.

Now dissolve two measures of sodium carbonate in a test tube one-third full of water and place the cloth in this solution. Shake the contents of the test tube thoroughly and then remove the cloth. Wash the cloth with water, and allow it to dry. The cloth will be dyed an iron buff. This color is produced by the precipitation of iron oxide upon the fiber by the alkaline salt, sodium carbonate.
<table>
<thead>
<tr>
<th>No.</th>
<th>Chemical Name</th>
<th>Formula</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Aluminum Sulphate</td>
<td>Al₂(SO₄)₃</td>
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<tr>
<td>2</td>
<td>Ammonium Chloride</td>
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<tr>
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<td>4</td>
<td>Borax</td>
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<tr>
<td>5</td>
<td>Boric Acid</td>
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<tr>
<td>6</td>
<td>Litmus Paper</td>
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<td>.05</td>
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<tr>
<td>7</td>
<td>Calcium Hypochlorite</td>
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<tr>
<td>8</td>
<td>Calcium Chloride</td>
<td>CaCl₂·6H₂O</td>
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</tr>
<tr>
<td>9</td>
<td>Calcium Carbonate</td>
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<tr>
<td>10</td>
<td>Camphor Gum</td>
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<tr>
<td>11</td>
<td>Calcium Oxide</td>
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<tr>
<td>12</td>
<td>Calcium Monophosphate</td>
<td>Ca(H₂PO₄)₂.H₂O</td>
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<td>Carbon Tetrachloride</td>
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<td>17</td>
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<td>19</td>
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<td>Copper Sulphate</td>
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<td>21</td>
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<td>22</td>
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<tr>
<td>23</td>
<td>Gum Arabic</td>
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<td>24</td>
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<td>26</td>
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<td>27</td>
<td>Insulated Copper Wire</td>
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<td>28</td>
<td>Logwood</td>
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<td>31</td>
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<td>(C₆H₄OH)₂(CO₆H₄)CO</td>
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<tr>
<td>34</td>
<td>Potassium Nitrate</td>
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<td>35</td>
<td>Potassium Permanganate</td>
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<td>Powdered Iron Sulphide</td>
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<tr>
<td>37</td>
<td>Powdered Charcoal</td>
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<td>38</td>
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<td>Sodium Bisulphate</td>
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<td>Sodium Thiosulphate</td>
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<tr>
<td>51</td>
<td>Strontium Nitrate</td>
<td>Sr(NO₃)₂</td>
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</tbody>
</table>
52—Sulphide Test Paper ................................ ................................ ...............................  .10
53—Sulphur S ................................ ................................ ................................ ..............  .10
55—Tartaric Acid COOH(CHOH)_2COOH ................................ ................................ ....  .20
56—Turmeric Paper ................................ ................................ ................................ ......  .05
57—Zinc Strip .............................................................................................................  .15
59—Nigrosine ................................ ................................ ................................ ...............  .10
61—Red Saunders ................................ ................................ ................................ .........  .05
63—Gum Benzoin .......................................................................................................  .15
65—Acetic Acid CH_3COOH .........................................................................................  .10
68—Denatured Alcohol C_2H_5OH .................................................................................  .05
69—Ammonia NH_4OH ..................................................................................................  .05
73—Strontium Chloride SrCl_2·6H_2O ..............................................................................  .10
74—Acetone (CH_3)_2CO ................................................................................................  .10
75—Chrome Alum Cr_2(SO_4)_3·K_2SO_4·24H_2O .................................................................  .10

MINERALS

X1500-A Galena ..............................................................................................................  .10
X1500-B Stibnite ............................................................................................................  .10
X1500-C Chalcopyrite ..................................................................................................  .15
X1500-D Pyrite .............................................................................................................  .10
X1500-E Magnetite .......................................................................................................  .10
X1500-F Pyrolusite ......................................................................................................  .10
X1500-G Sphalerite ....................................................................................................  .15
X1500-H Malachite .....................................................................................................  .10
X1500-J Calcite ...........................................................................................................  .05
X1500-K Fluorite .........................................................................................................  .10
X1500-L Halite .............................................................................................................  .05
X1500-M Orthoclase ...................................................................................................  .10
X1500-N Talc ...............................................................................................................  .10
X1500-O Apatite ..........................................................................................................  .10
X1500-P Muscovite ....................................................................................................  .05
X1500-Q Garnet ..........................................................................................................  .10
X1500-R Quartz .........................................................................................................  .10

APPARATUS AND EQUIPMENT

X861-B Wand .................................................................................................................  .05
X1547 Thermometer ....................................................................................................  .15
X1555-A Scale—Complete ..........................................................................................  .50
X1557 Test Tube Rack—Medium ..................................................................................  .20
X1570 Test Tube Rack—Small ......................................................................................  .15
*X1584 Gas Generating Bottle—Glass .........................................................................  .10
X1584-A Alcohol Lamp ...............................................................................................  .20
P-57-A Rod ...................................................................................................................  .02
P859 Ring for Ink Trick .................................................................................................  .05
P860 Black Cloth for Ink Trick .....................................................................................  .05
P1502 Test Tube ...........................................................................................................  .05
P1503 Glass Rod ..........................................................................................................  .05
The parts marked * are necessary to make the Gas Generating Apparatus. Kindly enclose check, money-order or stamps with your order.

THE A. C. GILBERT COMPANY
New Haven, Conn.