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 begin
think in the terms of chemistry, he ought to know first the difference between mate
and immaterial things. Material things are matter, and matter is something that o
pies space; something that takes up room. It can be either inorganic or organic m
rial. Immaterial things are not matter; for example, a thought is not matter; it does
take up room; it has neither length, breadth, nor thickness; you cannot feel, tast
see it. A good example of a material thing is air enveloping the earth; this has wei
and it takes up room. Water also is matter. In the form of a small raindrop, it has s
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 m
of the same substances of matter may be made to assume all the three different fo
Water, for example, is of common occurrence in nature as a liquid, but if the temp
ture falls low enough, as in winter weather, water is chilled and finally becomes a s
which we recognize as ice. On the other hand if the temperature rises high eno
the water becomes invisible and turns into a gaseous state, which we utilize in
form of steam as a source of power in the steam engine. Water is an inorganic
stance. The three forms of matter can also prevail among many organic compo
For example, if one heats a piece of camphor gum in an evaporating dish or in
cup, he will observe the following phenomena: The solid particle of camphor tur
a clear liquid. In other words, the camphor, when first heated, passes from a solid
a liquid state by melting. On continued application of heat, the camphor will fi
volatilize and become invisible. On leading the vapors of camphor over a cool
face, the organic vaporous material will solidify and deposit again as solid camp
During all these physical changes there is no alteration in the chemical compositio
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. G
for example, may be broken up into fine fragments, and even ground to a dust. In
manufacture of Portland cement we find a typical application of the production o
particles of inorganic matter by intensive grinding of mineral substances. Every s
particle of the dust of a pulverized substance represents the same composition as
of the original material before grinding. A wild animal running through a forest
a fox or deer, may emit odious particles in his travels that cannot be seen by any h
eye, yet the hound can easily pick up the scent and follow them for miles an
hours after the fox or deer has passed a given point. The odorous principle of
grant flower can be detected by the sense of smell in an atmospheric dilution
sponding to a percentage of composition that is indeterminable.

XPERIMENT 15—Division of Matter

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

PERIMENT 16—Division of matter

Take a crystal of potassium permanganate and dissolve it in a tumbler of water.
bserve the coloration of the fluid. The small particles of the original crystal are now
esent in all parts of the water. Their color in solution allows them to be seen. The
rformance of this experiment allows you to visualize to what an extent matter may
divided. Allow a part of the colored solution to evaporate to dryness and note that
e dissolved permanganate can be recovered in solid form.

PERIMENT 17—Division of matter

Drop into a clear dry test tube a crystal of iodine which may be obtained in any
ug store, and insert a common cork lightly into the mouth of the test tube (Figure
). Hold the test tube over an alcohol or candle flame and warm gently. Watch the

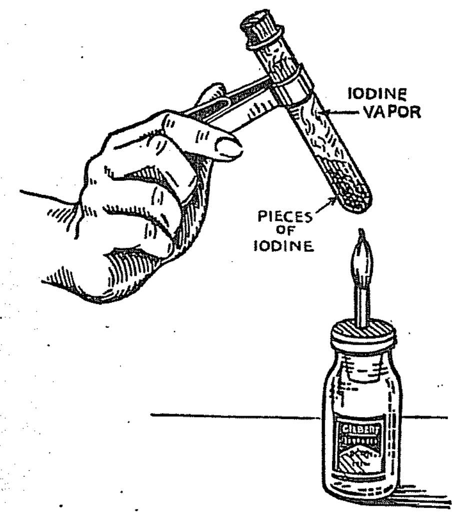

FIG. 17

utiful purple gas that is formed and observe how it creeps upward toward the
uth of the test tube. Here you have another demonstration of extreme divisibility;
solid particles of iodine having been volatilized by heat and divided into thousands
mall gaseous particles of iodine which are visible to the eye.

INORGANIC AND ORGANIC MOLECULES

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

MOBILITY OF MOLECULES IN SOLIDS, LIQUIDS AND GASES

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

PHYSICAL PROPERTIES OF MATTER

MASS AND VOLUME

All matter occupies space. The displacement of space occupied is called volu bushel, a quart, a liter represent, respectively, a unit of space or a measure of vo of space occupied by a particular substance. The space occupied by a known w of solid, liquid, or gas varies according to the density of the material. By s

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.

XPERIMENT 18—To demonstrate the specific gravity of liquids

Place a fresh egg in a glass full of water and notice that it sinks to the bottom. Now remove the egg and dissolve two 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 t formerly occupied before the change. Substances possessing this characteristic prop are spoken of as being elastic substances. The one outstanding illustration of a s stance having this unique property is ordinary rubber. In the stretching of a piec 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 m on the other substance. For example, a diamond will scratch, and even cut gl because it is harder than glass. You can cut ordinary metallic lead with a knife bl because it is softer than the metal of the knife.

FUNDAMENTAL PHYSICAL CONSTANTS WIDEL USED BY THE CHEMIST

FREEZ.NG POINT OR MELTING POINT

The melting point of a solid is that temperature at which it is converted to a liq It is a physical constant which is characteristic of all substances that are chemi pure. For example, ice has a melting point of 0° C., or 32° F. above which temp ture it is slowly converted into water. The freezing point of water (liquid) co ponds to the melting point of ice (solid).

SUPER-COOLING

This is the property of being able to retain the liquid form when cooled belo temperature of freezing or solidification. Liquids that assume such a physical are very susceptible to outside forces and easily assume a solid form when agitat

BOILING POINT

This is the temperature at which a liquid is converted into a vapor. The con is dependent upon the atmospheric pressure existing at the time of distillation o liquid. For example, water will boil at a lower temperature at a high altitude, a mountain top, than it will at sea level. In other words, the boiling point according to the variations in barometric pressure. We have many liquids that ca be distilled at ordinary pressure without decomposition, but if such substance distilled in a vacuum, they can be easily purified without destruction. The instru which is used by the chemist for determining melting points and boiling point thermometer, and two thermometer scales find application in chemical practice Fahrenheit and the Centigrade scales. According to the Fahrenheit scale, water fr at 32° above the zero point, and boils at 212°. According to the Centigrade scal freezing point of water is 0°, and the boiling point is 100°. In chemical practice also for recording scientific data in chemical publications we today make use of stants as recorded by both the Centigrade and Fahrenheit scales.

SUPER-HEATING

Many liquids of high boiling points are very susceptible to super-heating, due uneven absorption of heat when the liquid is being heated to its boiling point

hysical phenomenon is illustrated by the result of rapid heating of water in a test ube. If heated over a free flame without agitating the liquid the lower part of the olution will be over-heated and as a result there will be a sudden evolution of steam ollowed by a violent boiling of the fluid. This is referred to by the chemist as "bumpng." Unless precautions are taken during the heating of liquids, super-heating may esult, leading to serious accidents.

MEASURING TEMPERATURE

There are two different scales for measuring temperature, the Fahrenheit scale and he Centigrade scale.

The Fahrenheit scale is most commonly used in our houseohld thermometers and by he Weather Bureau, but in almost all scientific work, including chemistry, the Centirade scale is used. On the Centigrade scale the point at which water freezes under ormal pressure is marked zero, and the point at which water boils is marked 100.

The freezing point of water = 0 degrees Centigrade or 32 degrees Fahrenheit.

The boiling point of water = 100 degrees Centigrade or 212 degrees Fahrenheit. 1 egree Centigrade = one and four-fifths degrees Fahrenheit.

1 degree Fahrenheit = five-ninths degrees Centigrade.

To convert Fahrenheit to Centigrade or the reverse use these formulas:

C degrees = (five-ninths $\times$ F degrees = 32.).

F degrees = (nine-fifths $\times$ C degrees) + 32.

THE ELEMENTS AND CHEMICAL CHANGE

All of the changes which take place in chemical reactions are based on the actions f certain substances which the chemist calls "elements." A boy or girl should, therere, first acquire the correct meaning of this term if he or she is to perform underandingly chemical experiments. By elements the chemist means those substances hich he is not able to break up into simpler substances. An element may be a solid, ich as copper or iron; a liquid, such as mercury; or a gas, such as oxygen or hydrogen. is also important to emphasize here the fact that some elements can exist in all of e three different physical forms. For example, ordinary iron is a solid, but will ecome a liquid if heated hot enough, or if heated at a very high temperature, it will ecome a gas. Mercury can be heated to form a gas, or it can be cooled to form a solid. he gas oxygen can be cooled to a liquid: or when cooled still further, to a solid. In ll these physical changes of iron, mercury and oxygen, brought about by changes of mperature, 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 ey combine in millions of different ways to form every substance that we know of on ır earth. When elements combine with each other they form what the scientist calls mpounds." When elements are converted into compounds, they lose their chemical entity, and we create new substances possessing different properties. Such phenomena e explain as chemical changes, and the chemist speaks of such chemical changes also chemical reactions. For example, sulphur is an element and oxygen is an element. hen the sulphur is heated it attracts to itself the element oxygen, and undergoes a emical change. In other words, the sulphur and oxygen undergo a chemical reaction form a compound which is a gas—sulphur dioxide. This gas finds wide commercial plication as a bleaching agent, and also in the manufacture of electric refrigerators. ie study of the elements and compounds, their properties, their chemical changes, d reactions, is called Chemistry.

THE ATOMIC THEORY

Under the heading—Inorganic and Organic Molecules—we have a definition of t
term "molecule," and stated that this is the smallest particle into which matter can
divided without changing its chemical nature. This definition of a molecule applies
both elements and compounds, and just as long as one does not subject an element
a compound to an experimental condition which leads to a chemical change or rea
tion, the substance is said to retain its original form.

When a chemical change or reaction takes place, the molecules of an element
compound are destroyed and new molecules are formed. In order to interpret su
phenomena, it became necessary for the chemist to originate an imaginary concept
postulation as a working hypothesis. The result was the creation of a general law
nature which has been for several years the fundamental basis of chemical reasonin
This fundamental theory of chemistry is known as the Atomic Theory. The chemis
explanation or chemical change or chemical reaction on the basis of the Atomic Theo
is as follows: He assumes that there are particles in matter that are much smaller th
the molecules to which we have previously referred. This division of molecules tak
place under conditions favoring a chemical change, and when molecules break up in
these new imaginary particles the substance becomes very unstable and very reacti
The chemist has named these invisible and imaginary units "atoms," and when co
pounds are formed by interaction of elements or otherwise, it is the atoms that
involved, and new compounds are formed. In other words, molecules of elements
compounds lose their physical identity when they react chemically to form new su
stances, and are converted first into atoms. These atoms are very unstable and can
exist alone, and consequently seek other atoms to make new molecules. The result,
chemical sense, is a chemical reaction, with formation of a new substance havi
entirely different chemical and physical properties than those of the original substan
brought together.

Therefore, as a result of the above reasoning, chemists have adopted the law of t
atom to guide them in their chemical reasoning. It is as follows: *An atom is the sma
est particle into which matter is divided in chemical changes.* Chemistry then has
much broader meaning when we work according to such a theory, and may be defi
as the science of atoms, and how atoms combine with each other to form compounds.

The interaction of sulphur and oxygen may now be explained as follows: Wh
these two elements combine with each other it is not the molecule of sulphur a
oxygen that react, but their atoms. The atoms on being formed cannot exist alone,
attract each other, leading to the formation of a new compound in which the pro
ties of sulphur and oxygen have been lost entirely. An atom of sulphur (S) combi
with two atoms of Oxygen (O_2) to form a new substance, or gas (SO_2). The combi
tion of two different atoms in this case leads to the formation of a new molecule.

THE MODERN CONCEPTION OF THE ATOM

Great advances in the science of chemistry and physics have been made by scien
in the last twenty-five years. New theories regarding structure have been advan
which have led to a complete revolution or previous concepts. According to the ne
theories of the structure of matter, the atom is not the smallest particle which fu
tions in a chemical change, but we now conceive the existence of a still smaller
than the atom,—namely, the electron. This new conception of chemical change is
trical in nature and the electron is the unit of electrical charge. These newer pos
tions are constantly undergoing modification and are far too advanced and theore
to be comprehended by boys and girls for whom this manual is written, but it is

ut of place to record here some of the conclusions that have been accepted and which
re influencing the development of modern chemical reasoning. The modern concepts
egarding the structure of atoms may be stated briefly as follows:

1. Each of the 92 elements which we believe to constitute all matter is made up
f atoms.
2. Atoms in turn consist of units which we call protons and electrons.
3. Protons are units charged positively and electrons are units charged negatively.
4. Every atom contains an equal number of positive and negative charged units.
5. The atom owes the greater part of its weight to the positively charged protons.
6. All of the protons and a part of the electrons of each atom are concentrated
ithin a relatively small space at the center of the atom. The remaining electrons are
ocated in layers or "shells" outside of the nucleus. The nucleus may be conceived
herefore as the sun of a planetary system around which rotate the planets (electrons).

KINDS OF CHEMICAL CHANGE

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

CHEMICAL CHANGE THROUGH DEGRADATION BY HEAT

XPERIMENT 19—Decomposition of sugar

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

DECOMPOSITION OF AN INORGANIC SALT BY HEATING

XPERIMENT 20—Decomposition of sodium thiosulphate

Place 3 measures of sodium thiosulphate in a clean, dry test tube and, using a
t tube holder so as not to burn the fingers, heat over the alcohol lamp. You will
tice that moisture forms on the inside of the test tube and some steam will be given
. Sodium thiosulphate contains water of crystallization which is driven off in the

form of steam when the substance is heated. On further heating you will notice th sulphur is driven off and is deposited on the upper part of the test tube. You will r ognize the odor of hydrogen sulphide gas. The material left in the bottom of the tu consists of sodium sulphate and sodium sulphide. The results of heating may be repr sented as follows:

sodium thiosulphate + heat = water + sulphur + hydrogen sulphide
+ sodium sulphate + sodium sulphide.

CHEMICAL CHANGE BY DOUBLE DECOMPOSITION

EXPERIMENT 21—Action of ferric ammonium sulphate on calcium oxide

In a test tube of cold water add ½ measure of ferric (iron) ammonium sulpha Place the thumb over the mouth of the test tube and shake to dissolve the solid. N add ½ measure of powdered calcium oxide and shake again. A reddish brown preci tate is formed.

The iron of the ferric ammonium sulphate changes places with the calcium of calcium oxide to form calcium sulphate and ferric (iron) hydroxide, which is insolu in water, and appears as a reddish-brown precipitate.

EXPERIMENT 22—Action of aluminum sulphate on strontium nitrate

Dissolve 1 measure of aluminum sulphate in a test tube ¼ full of water. In anot test tube ¼ full of water dissolve 2 measures of strontium nitrate. Now pour the c tents of the second tube into the first and observe the formation of a white precipit

The aluminum of the aluminum sulphate changed places with the strontium of strontium nitrate to form the soluble compound aluminum nitrate, and the white pr pitate of strontium sulphate which is very insoluble in water.

SUBSTITUTION OR THE DISPLACEMENT OF ONE ELEMENT BY ANOTHER

EXPERIMENT 23—Action of iron on copper sulphate

Add 1 measure of copper sulphate to a test tube half full of water. Close the mo of the test tube with your thumb and shake until all the solid is entirely dissol This gives a blue solution of copper sulphate commonly known as blue vitriol.

Now add 1 measure of powdered iron to the copper sulphate solution and sh the contents of the test tube for a few minutes. The green color of the copper sulp solution will gradually disappear and the iron will become covered with a red dep of copper.

EXPERIMENT 24—Action of zinc on copper sulphate

Repeat the preceding experiment, using powdered zinc in place of the iron. No that practically the same results are obtained.

EXPERIMENT 25—Action of magnesium on copper sulphate

Repeat the preceding experiment, using powdered magnesium in place of the i Notice that in this experiment similar results are obtained.

EXPERIMENT 26—Action of zinc on hydrochloric acid

Dissolve 3 measures of sodium bisulphate and 4 measures of ammonium chlori a test tube ¼ full of water. The sodium bisulphate reacts with the ammonium chlo to form hydrochloric acid which is soluble in water. Heat cautiously over an alc

lamp until a clear solution is obtained. Now add to this acid solution 1 measure of powdered zinc and you will observe an immediate reaction and bubbles of gas will be generated. This gas is hydrogen formed by action of zinc on the hydrochloric acid.

CHEMICAL CHANGE BY DIRECT UNION OF ELEMENTS

EXPERIMENT 27—Union of zinc with sulphur

Both zinc and sulphur are elements. Mix 1 measure of powdered zinc with an equal amount of sulphur on a piece of white paper. This is not a chemical compound, for we could readily separate the sulphur from the zinc mechanically by treating the mixture with carbon bisulphide which would dissolve the sulphur and leave the zinc behind.

Place this mixture on the cover of a baking powder can and heat over the candle flame or alcohol lamp for a few minutes, keeping the face a safe distance away from the cover until the reaction is apparently over. You will note that the sulphur and zinc suddenly flash up and combine. The zinc reacts with the sulphur directly to form a compound called zinc sulphide. This substance is different from the original mixture, for if we break this up into a powder and treat it with carbon bisulphide we can not dissolve out the sulphur, for it is now in chemical combination with the zinc.

Break up the zinc sulphide which you have just made into a powder by grinding in a mortar and put some of this into a dry test tube. Add one measure of sodium bisulphate, a few drops of water and warm over a flame for a minute. Remove the test tube from the flame and smell the gas given off. This is hydrogen sulphide. This is the gas formed in eggs when they decompose.

EXPERIMENT 28—Union of magnesium with oxygen

Place a small amount, only ½ measure, of powdered magnesium in the spoon and heat it over the alcohol flame, keeping your face at a safe distance. Notice the sudden flash and the light powdery substance remaining. The metal magnesium combines with oxygen of the air to form a white powdery substance called magnesium oxide.

Explanation of the behavior of the metals in the preceding experiments: The metals may be arranged in what is known as the electromotive series; that is, in the order in which they dissolve in acid solution. Metals which dissolve readily, for example, in sulphuric acid will displace those metals which do not dissolve in this acid solution or which dissolve only with difficulty. Any metal will replace any other metal below it in the electromotive series, thus:—

magnesium metal + iron sulphate = magnesium sulphate + iron
zinc metal + copper sulphate = zinc sulphate + copper
tin metal + silver nitrate = tin nitrate + silver
copper metal + mercury nitrate = copper nitrate + mercury

THE ELECTRIC CELL

This is the fundamental principle of the Daniell Electric Cell. The voltage or strength of an electric cell depends upon the difference between the electrode potentials of the metals used for the two poles (+ and —) of the battery. For example: a zinc-copper battery couple gives a greater Electro Motive Force than a zinc-lead couple or an iron-copper couple. The farther apart the elements are in the electromotive series the greater will be the electrical voltage of the battery cell.

ELECTROMOTIVE SERIES

Element	Electrode potent
Iron (ferrous)	+0.4410
Tin	+0.1360
Lead	+0.1220
Iron (ferric)	+0.0450
Hydrogen	0.0000
Copper	—0.3400
Silver	—0.7978
Mercury	—0.7986

AMERICA'S GENIUS IN THE FIELD OF ELECTRICIT

We often hear the question asked: Did the founders of science make their contrib tions before they were thirty or afterwards? Practically all the pictures that are ava able of the different founders of science represent them as old or middle-aged men. is true, however, that the founders of science actually did things before they w thirty. The things that they did were discoveries made, theories advanced, laws form lated, classic experiments performed, and methods of teaching which commanded t attention of the public. The important things that they did did not receive much att tion at the time they did them, but since their work, they have been given credit a recognition. Thomas A. Edison began his important work when he was a very you man, and his invention of the incandescent lamp was one of his earliest contributio Mr. Edison was a ceaseless worker and continued to take an active interest in his wo until his death. Every American boy should be proud of the record of this wonder man.

THE ATMOSPHERE

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

OXYGEN

Oxygen of the air plays a very important role in our everyday life. We brea this element into our lungs and from these organs it is carried by the blood-stre throughout the body to combine with the waste products of body metabolism. Th waste materials are oxidized by the oxygen, carried in the blood stream to car dioxide which is carried back to the lungs by the blood and is there passed out into air when we breathe. It is very essential, therefore, that we breathe in fresh air if wish to enjoy good health. Pure oxygen is a very active element, and if it were

or the fact that the oxygen of the air is diluted with nitrogen gas, a very inactive ubstance, 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 ot burn unless air rich in oxygen is constantly supplied so that the fuel can have lenty of oxygen to support combustion. Substances cannot burn without oxygen.

OXYGEN EXPERIMENTS

XPERIMENT 29—To remove oxygen from the air

Place a candle in the center of an ordinary wash pan by allowing a little of the nelted wax of the candle to fall on the pan to stick the candle firmly. Then pour into he pan two inches of water (Figure 18). Light the candle and place over it a mason r fruit jar. Be sure that the jar is high enough so that the flame does not come too lose to the top of the jar.

You will notice that very soon the flame grows dim and finally dies out, the oxygen f the air within the jar having been entirely used up. Notice that the water begins to ise inside the jar and stands at a higher level than the water in the pan. This is ecause the oxygen was removed, forming a partial vacuum which drew the water up nto the jar. The xygen in the jar nited with the arbon in the ame to form carbon dioxide, a gas hich dissolves water, and ith hydrogen to orm steam, hich condenses water. The gas emaining in the r is nitrogen.

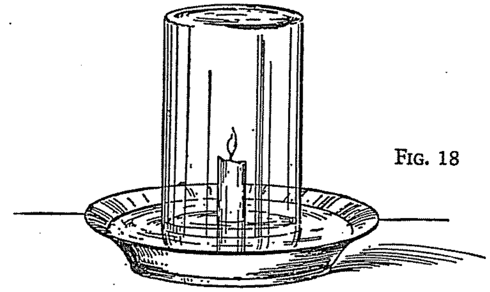

Fig. 18

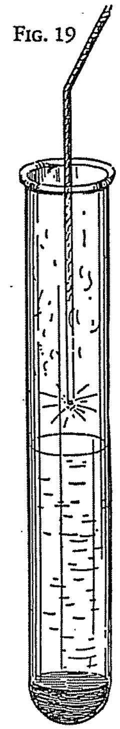

Fig. 19

XPERIMENT 30—Preparation of oxygen and how to test for it

Fill a test tube about half full of ordinary hydrogen peroxide or oxygen solution (which may be purchased at a drug store) and add or 2 measures of manganese dioxide. Notice what takes place.

Now light a splinter of wood or string, blow out the flame, being sure hat there is a spark remaining on the wood or string and lower the park into the tube above the liquid. (Figure 19). Notice that the wood r string takes fire and burns with a flame. This is the way to test or oxygen.

Hydrogen peroxide is a liquid composed of two atoms of hydrogen nd two atoms of oxygen, just as water is composed of two atoms of ydrogen and one atom of oxygen. The manganese dioxide is added to ake the hydrogen peroxide give up part of its oxygen and in doing so emains unchanged itself. The hydrogen peroxide is decomposed into ater and oxygen. A substance like manganese dioxide which causes reaction to take place or speeds up a reaction and at the same time emains unchanged itself is called a "catalytic agent." We have many llustrations of catalytic agents or reaction promoters in chemistry, and any of them find wide commercial applications.

EXPERIMENT 31—Preparation of oxygen from potassium permanganate

Place two measures of potassium permanganate in a clean, dry test tube and h over an alcohol lamp. Test for the presence of oxygen the same way as in the pre ing experiment.

Many substances like potassium permanganate contain large amounts of oxyg part or all of which is liberated on heating.

HYDROGEN PEROXIDE

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

EXPERIMENT 32—Behavior of hydrogen peroxide toward blood

Place a drop of blood on a small watch glass and then pour over the drop of bloo small quantity of hydrogen peroxide solution. Then mix the blood with the pero solution by stirring with a glass rod. Notice that the peroxide is decomposed with lution of bubbles of oxygen. At the same time the red color of the blood is lost. blood is destroyed by the action of the generated oxygen. Many forms of bacteria killed by contact with hydrogen peroxide.

EXPERIMENT 33—A standard test for hydrogen peroxide

Make a solution of potassium permanganate by dissolving 2 crystals of the s salt in water as follows: Fill a test tube ¼ full of water and add the crystals to water. Then close the mouth of the test tube with the thumb and shake vigoro until the crystals dissolve.

In a glass one-half full of cold water put 3 drops of the potassium permang solution; mix thoroughly and notice the pink color of the solution. Now to this s tion add 5 drops of the hydrogen peroxide solution to be tested. If the pink col destroyed, the hydrogen peroxide solution may be considered of correct stre Both the potassium permanganate and hydrogen peroxide are destroyed. They ca exist in the presence of each other.

OXIDATION

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

Oxidation is an important chemical process. We obtain heat to warm our h in winter, and power to run machinery in our factories by burning (oxidizing) w oil and coal. Our houses are lighted by burning (oxidizing) gas or kerosene, o electricity that is generated by machinery run by burning (oxidizing) fuel. W gasoline is ignited and exploded in the cylinders of an automobile engine, the gas suddenly unites with the oxygen of the air which has been drawn into the cylin An ordinary house heating furnace is an oxidizing machine, and even man an living organisms (animals) are likewise active oxidizing machines. By means of

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.

REFRIGERATION AND AIR CONDITIONING

Reversed refrigeration, or the process of heating a house in winter by means of the same equipment for cooling it in summer, is an idea which is being carefully investigated today by engineering concerns interested in the manufacture of air-conditioning apparatus. In summer, air-conditioning equipment absorbs heat from inside the house, takes it to the outside and discards it, just as an electric refrigerator takes up heat from inside the food compartment and releases it into the room. In winter the cycle is reversed. Heat is taken up from out doors and brought inside to warm the house. Coils inside the house, which formerly absorbed heat, become radiators, while the outside coils, instead of throwing off heat, absorb warmth from the outside air. There are many problems yet to be solved before reversed refrigeration equipment is commercially successful, but the principle is constantly finding new applications and a promising future is ahead for new and important commercial developments.

CHEMICAL OXIDATION EXPERIMENTS

EXPERIMENT 34—The making of a chemical fire

There are many methods of making "chemical fire." One of these is dependent upon the fact that glycerine when in contact with solid potassium permanganate takes up oxygen from the potassium permanganate so rapidly that intense heat is created. The heat finally becomes so intense that it causes the glycerine to vaporize and the vapor finally takes fire, burning with a purple flame. The color of the flame is due to the metallic particles of potassium, resulting from the decomposition of the permanganate.

EXPERIMENT 35—How to make a fire without a match

Upon an ordinary small tea saucer or a cover of a tin can put just three drops of glycerine—*no more.* Then place on the glycerine about 5 measures of potassium permanganate crystals. *Let stand in a safe place.* In a few seconds the whole mass will begin to smoke, and if the proper proportions of chemicals have been added, as indicated, the glycerine will suddenly burst into flame and burn with a blue color.

EXPERIMENT 36—Fire ink

Place ½ spoonful of potassium nitrate in a test tube and add ½ 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 37—Oxidation of metallic zinc

Make a mixture of 10 measures of ammonium nitrate and 1 measure of ammoni chloride on a metal pan or plate and spread the mixture out in a thin layer. N sprinkle over the top of this mixture 5 measures of powdered zinc and allow 1 d of water to fall into the mixture.

Notice that the mass soon burns, the oxidation taking place so rapidly that the z takes fire. The oxygen is furnished in the reaction by the ammonium nitrate, and z is converted into zinc oxide. Metallic iron undergoes a similar change when expo to air and the metal burns red due to oxidation. This is spoken of in common langu as "the rusting of iron."

EXPERIMENT 38—How to make a fuse

A very good fuse can be made by soaking a cotton string in a solution of potassi nitrate or saltpetre for a few minutes and then allowing the string to dry. Allow string to be suspended before drying. You can time your fuse by using the pro length of string. The nitrate solution is prepared by dissolving ½ spoonful of po sium nitrate in a test tube containing ½ inch of water, and then shaking until al dissolved.

EXPERIMENT 39—Oxidation of an element by means of a nitrate

Heat on your spoon one measure of potassium nitrate until the salt is mol Then drop a pinch of sulphur into the molten potassium nitrate and notice the sud flash. The sulphur will be oxidized by the oxygen from the potassium nitrate to f sulphur dioxide. Note the odor of the burning sulphur. In the preceding experim the burning of the cotton fuse leads to the formation of carbon dioxide, an odor gas, while sulphur burns under similar conditions to give sulphur dioxide, havi characteristic penetrating odor.

EXPERIMENT 40—To show the increase in weight upon heating iron in the air

A small bundle of iron wool is counterbalanced on a beam balance. It is then h by means of tongs, above an alcohol flame until it ignites. The iron wool is t removed from the flame until it stops sparking. The entire process is repeated u all the iron has completely burned. Upon reweighing, the increase in weight is apparent. One must be careful not to burn the wool too rapidly so as not to lose much of the iron in the form of sparks.

EXPERIMENT 41—Oxidation of spices

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

EXPERIMENT 42—Suffocating a burning candle

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

EXPERIMENT 43—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 44—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 jar 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 45—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 46—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 47—Oxidation of zinc

Polish a strip of zinc metal and repeat the air oxidation experiment applied with iron fragments.

EXPERIMENT 48—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 49—Combustion of charcoal

Heat three measures of potassium nitrate in a dry test tube over your 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 50—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 51—Burning paper

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

EXPERIMENT 52—Oxidizing copper

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

EXPERIMENT 53—Oxidizing iron

Repeat the above experiment using a piece of iron wire.

EXPERIMENT 54—Oxidizing aluminum

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

EXPERIMENT 55—Oxidizing nickel

Repeat the above experiment using a piece of nickel wire.

EXPERIMENT 56—Oxidizing zinc

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

EXPERIMENT 57—Oxidizing silver

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

EXPERIMENT 58—Asbestos insulation

Repeat the preceding molten postassium nitrate experiment with some asbe
fibers. What happens?

EXPERIMENT 59—Cotton fiber

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

EXPERIMENT 60—Oxidizing sulphur in copper sulphate

Repeat the preceding experiment by fusing potassium nitrate and then drop
into the hot fluid crystals of copper sulphate. Observe the behavior and note whe
you actually have an oxidation with formation of sulphur dioxide.

PROTECTION AGAINST FIRE

Intensive oxidation of combustible material leads to generation of heat and,
final result, to a conflagration. Cloth, wood, paper and other substances may be rend
fireproof by treating them with the proper chemicals. Ammonium chloride o
ammoniac (NH_4Cl) is a cheap salt which can be used for this purpose. The a
to be fireproofed is dipped into or soaked in a strong aqueous solution of ammo
chloride and then dried. When such treated material is heated, the ammonium chlo
is decomposed with liberation of ammonia and hydrochloric acid, and a fire is
vented, as neither the ammonia or hydrochloric acid will support combustion. W
they are generated they smother the flame and conflagration is prevented. The cu
and scenery of theaters and tapestries in public buildings are fireproofed as a prote
against fires. Fireproofed wood finds important commercial use as a constru
material. Such chemically treated materials cannot be set on fire by sparks or fla
Tin salts find commercial application in fireproofing.

XPERIMENT 61—To fireproof cloth or paper

Take a strip of paper or linen and immerse it in a solution made by dissolving one
aspoonful of ammonium chloride in a test tube ⅓ full of water. When the paper or
nen is dry, try to light it with a match. You will see that it burns while held in the
ame but will go out just as soon as the flame is removed.

KPERIMENT 62—To fireproof wood

Wood is also treated sometimes with a strong ammonium chloride solution. Another
ay 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
ass). Allow the coating to dry for twenty minutes, then light the match. The flames
ill go out just as soon as it reaches the portion that has been dipped in the water
ass solution.

KPERIMENT 63—Fire-proofing cloth

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

Dissolve 12 measures of ammonium chloride in a test tube ⅓ full of water. Put a
ece of cotton cloth 2 or 3 inches square in the bottom of a glass and pour the liquid
the test tube over it. Stir the cloth around until it is wet through, then let it dry
d try to light it with a match. You will find that it will burn while held in the
me, but just as soon as the match flame is removed it will go out.

KPERIMENT 64—Fireproofing with sodium tungstate

Cloth, paper, wood and similar inflammable substances may be fireproofed by treat-
g them with sodium tungstate. This process is frequently used in connection with
e curtains and scenery for theaters. The woodwork on battleships is also treated in
is manner so that it will not take fire from the explosion of shells.

KPERIMENT 65—Fireproofing with sodium silicate

Sodium silicate solution or water glass is often used for fireproofing. Wood is fre-
ently fireproofed by means of sodium silicate. This liquid if applied to paper or
oth 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
odium silicate solution). Let the coating which is obtained dry about 15 minutes,
en light the match. There will be no danger of burning your fingers, for the flame
ill go out as soon as it reaches the water glass.

FIRE EXTINGUISHERS

Since carbon dioxide does not burn nor support combustion, it is used in fire
tinguishers. You are all familiar with the hand fire extinguisher. Remember the
structions: "To operate, turn upside down." This apparatus is really no more nor
s than a huge siphon, the kind you get carbonated or seltzer water from.

In the large vessel is a dilute solution of sodium carbonate. In the bottle is strong
lphuric acid. The cork is made of lead and fixed so that when the tank is turned
side down it falls from the bottle just enough to allow the sulphuric acid to trickle
ough slowly. (Figure 20). (A) shows an interior view of the fire extinguisher: (B)
ows what happens when the extinguisher is turned upside down.

The acid liberates carbon dioxide from the sodium carbonate just as you liberated
bon dioxide from sodium carbonate with tartaric acid. The free gas creates a high
essure in the tank, causing large quantities of gas to dissolve in the water and forcing

out a stream of gas and water. Carbon dioxide is heavy and surrounds the flame w a blanket of unburnable gas, which prevents access of oxygen and in that way smoth the flame.

Quite recently a new style fire extinguisher has come into use. The container is b like a hand pump. In the pumplike arrangement is a liquid called carbon tetrachlor This is a rather marvelous liquid. It volatilizes, that is, it is converted into a ga quickly as alcohol or gasoline but it does not burn. You are familiar with the ex sive power of gasoline. Here is a vapor which defies all attempts to burn it.

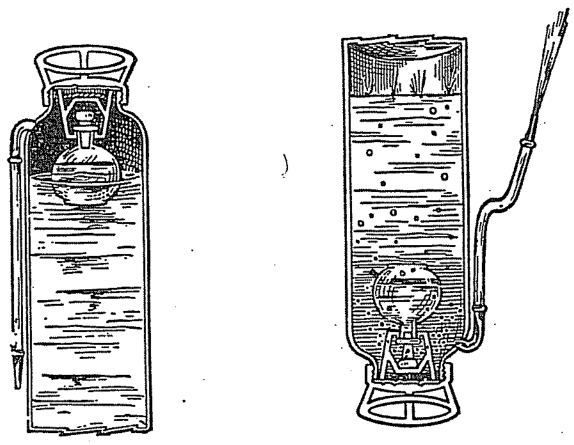

FIG. 20

When directed at the base of the flame the spray of carbon tetrachloride qui forms a gas which surrounds the burning oil or wood or whatever it is like a bla and prevents the access of oxygen. Without oxygen there can be no combustion, so fire is smothered.

Carbon tetrachloride is also a splendid solvent. It is used to remove grease and p spots from clothing and to clean white leather. You have probably noticed adve ments of spot removers which do not burn. All of these contain carbon tetrachlori

EXPERIMENT 66—Carbon tetrachloride, a fire extinguisher

Pour a little carbon tetrachloride on a piece of paper and light the paper wi match. Notice that the paper will not burn, proving that carbon tetrachloride not support combustion and will not burn. This is an example of a wet fire extingui

EXPERIMENT 67—A hand grenade fire extinguisher

Take 2 test tubes of crude calcium chloride; 2 spoonfuls of common salt and 1 of water and place in thin bottles. In case of fire, a bottle of this mixture throw that it will break near the flames will put the fire out. This mixture is better cheaper than most of the grenades sold for the purpose of fire protection.

HYDROGEN

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

Because of its lightness, hydrogen is used for filling airships, dirigibles and balloons Figure 21). During the last World War, hydrogen was used in enormous quantities, nd was generated cheaply by treating the metal aluminum with sodium hydroxide. hese materials were economical to use in large quantities and could be easily trans- orted from place to place.

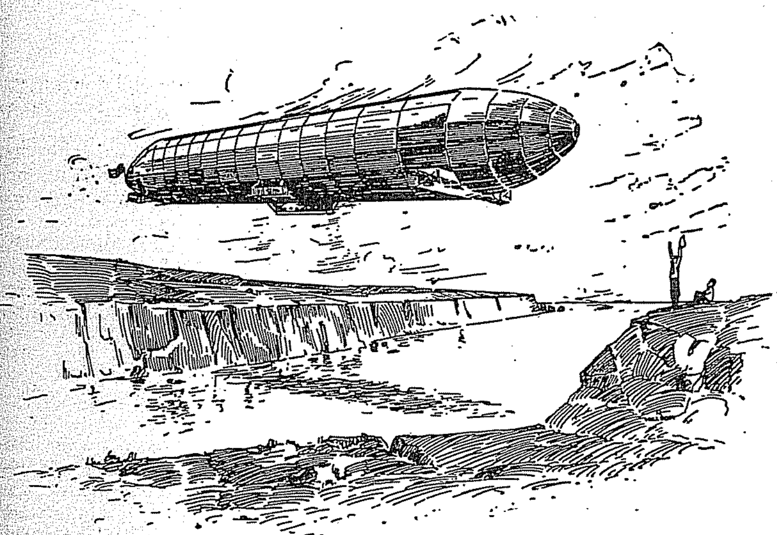

FIG. 21

HELIUM AND AVIATION

Owing to the explosive nature of hydrogen gas it is not as widely used today as rmerly for inflation of dirigibles and balloons. The gas helium, which is non-com- stible, is being substituted for this purpose. The wreck of dirigibles has demonstrated