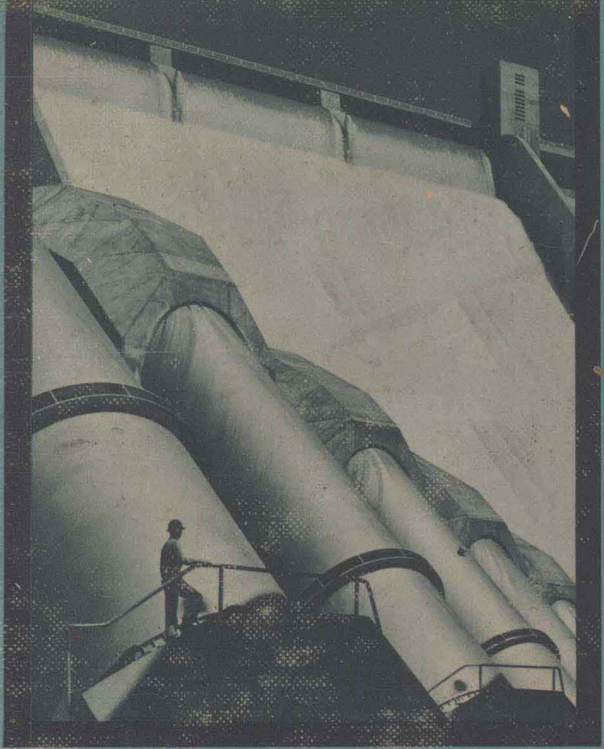
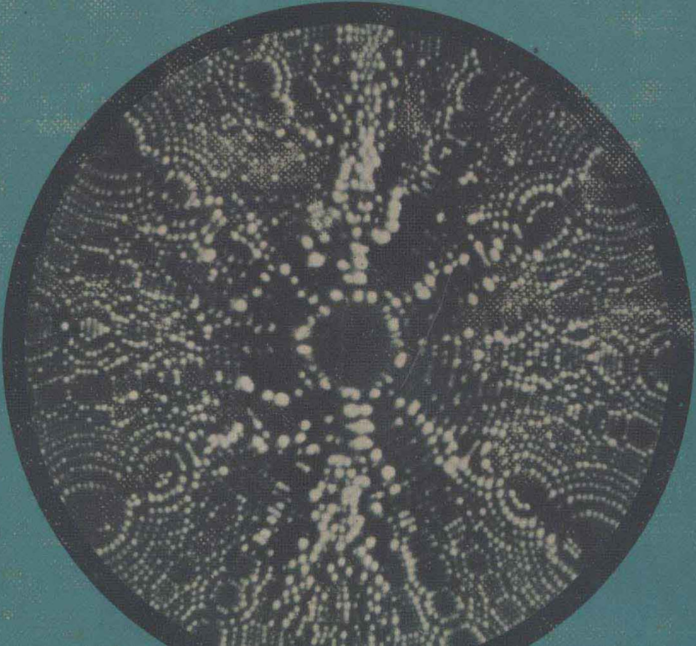


The World of MATTER–ENERGY



The World of MATTER–ENERGY

PAUL F. BRANDWEIN

ALFRED D. BECK

VIOLET STRAHLER

LELAND G. HOLLINGWORTH

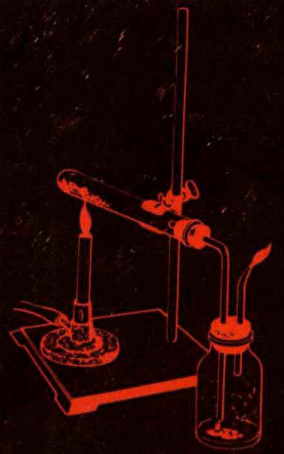
MATTHEW J. BRENNAN

Editorial Collaborators

Jerome J. Notkin
Clifford R. Nelson
Herbert Drapkin

Harcourt, Brace & World, Inc.

New York Chicago Atlanta Dallas Burlingame



Matter undergoing change

Matter and Its Changes

The chemist in the picture opposite is a young man. The idea behind the structure of the compound he is analyzing is also young—very young, as ideas go. Fifty years ago he could not have done the work he is doing; the ideas were not yet developed.

To understand compounds and their structure, the basic ideas concerning matter and energy need to be understood. To reach this understanding is the aim of the study you are about to begin. Like most work in science, we begin this year's study not by groping in the dark but by building on what is known. We know this:

> **Matter and energy undergo changes, but the total amount of matter and energy in the universe remains constant.**

A great idea such as this is often called a major concept of science. It is basic to the unit you are about to study.

You probably have some sound knowledge which underlies this idea. Examine the statements below and make such responses as you can at this time. After you have finished your work in this unit, return to the statements and decide whether you would alter the responses you have made.

1. The element iron is made up of (a) two kinds of atoms, (b) one kind of atom, (c) several elements, (d) compounds.
2. If a grain of sugar could be divided into smaller and smaller pieces, eventually the smallest possible piece of sugar would be one (a) atom, (b) proton, (c) element, (d) molecule.
3. Atoms of such elements as radium and uranium are continually breaking up because they are (a) elements, (b) radioactive, (c) heavy, (d) compounds.

THE AUTHORS

Paul F. Brandwein, *Director of Programs, The Pinchot Institute for Conservation Studies; General Editor and Consultant to Schools, Harcourt, Brace & World; formerly Chairman, Science Department, Forest Hills High School, New York, New York*

Alfred D. Beck, *Assistant Director of Science, Junior High School Division, Board of Education, New York, New York*

Violet Strahler, *Instructor, Chemistry and Science, Dayton Public Schools, Dayton, Ohio; Visiting Instructor, Physical Science, Miami University, Oxford, Ohio*

Leland G. Hollingworth, *formerly Director of Science, Brookline Public Schools, Brookline, Massachusetts*

Matthew J. Brennan, *Director of Field Studies, The Pinchot Institute for Conservation Studies; Chief, Conservation Education, U.S. Forest Service*

THE EDITORIAL COLLABORATORS

Jerome J. Notkin, *author of the chapter activities; Associate Professor, Division of Education, Hofstra University, Hempstead, New York; formerly Science Supervisor, Third Supervisory District, Suffolk County, New York*

Clifford R. Nelson, *Head of Science Department, Weeks Junior High School, and formerly Consultant in Science, Newton, Massachusetts; co-author, with* Violet Strahler, *of the laboratory texts,* Discoveries in Science *and* Explorations in Science

Herbert Drapkin, *co-author of the Teacher's Manual; Science Division, Fullerton Junior College, Fullerton, California; Teacher of Elementary Science Teaching Methods, University of California Extension Division, Los Angeles, California*

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COVER PICTURES

FRONT COVER: *top left,* Shasta Dam, California; *top right,* a student and his automatic tracking device for telescopes; *bottom,* atoms in a crystal of tungsten.
BACK COVER: *top,* Horsehead Nebula in Orion; *bottom,* views of gears in a watch.

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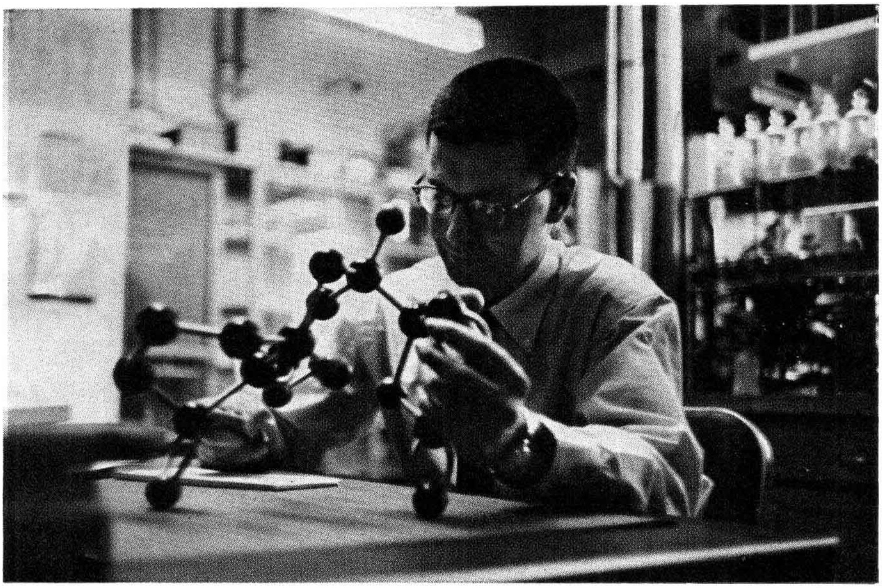


CONTENTS

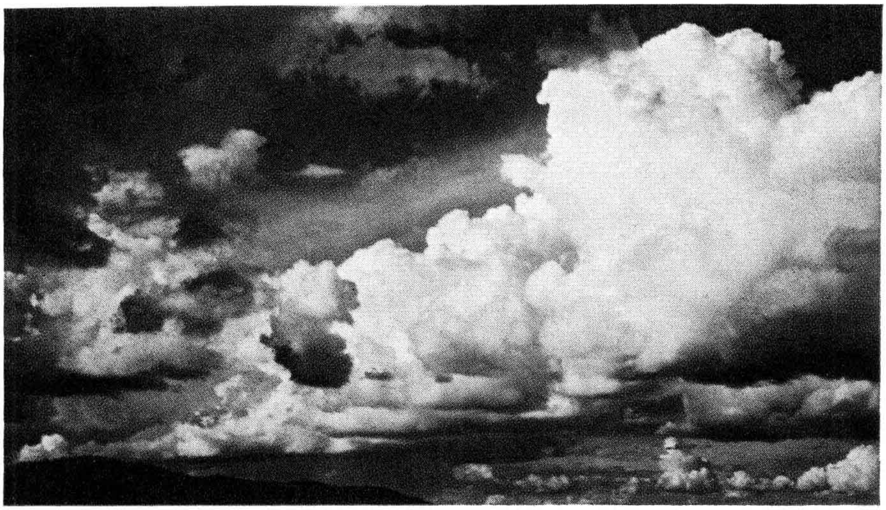
UNIT 1 MATTER AND ITS CHANGES

All matter is continually undergoing changes of state or combining or breaking down to form new substances. For these physical and chemical changes, energy is required in different forms, and energy is released in the process. Yet the total amount of matter and energy in the universe remains constant.

UNIT 2 RESOURCES IN THE EARTH'S CRUST

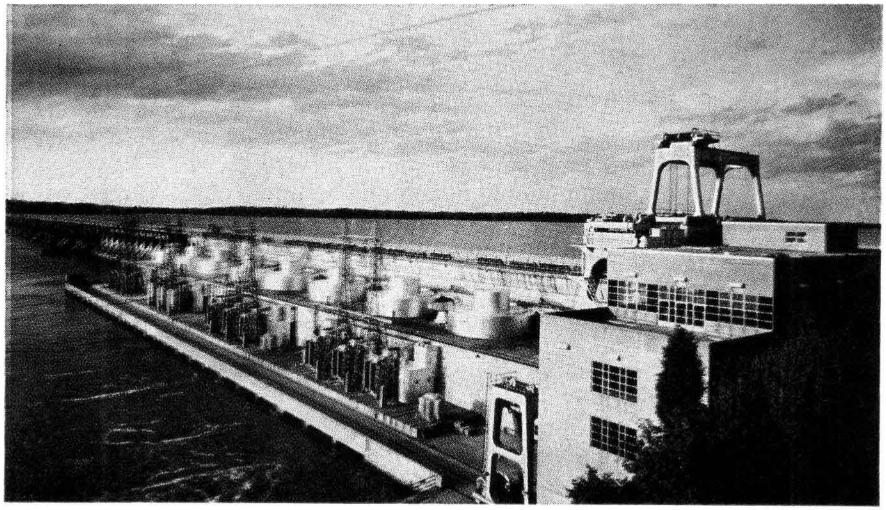
Stored in the rocks of the earth's crust and in the waters that cover it are the many forms of matter from which living things obtain energy. Man has learned to use these stores of matter-energy, these resources, to serve his needs. In fact, all organisms take their matter and energy from their environment.

Color Plates
THE EARTH AND ITS ATMOSPHERE
at page 52



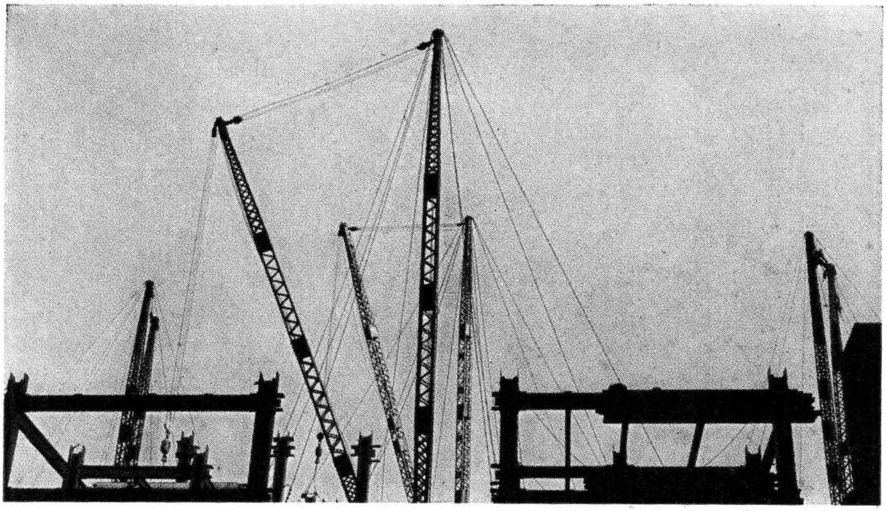
UNIT 3 THE EARTH'S AIR OCEAN

Like an ocean, the earth's atmosphere is in constant motion, undergoing great energy changes. Water evaporates into the air, clouds form, rain falls, winds blow. All living things are adapted to these changes in the physical environment; but, unlike most other organisms, man is adapted—mainly by his brain—to study these changes and can attempt to predict and modify the weather.



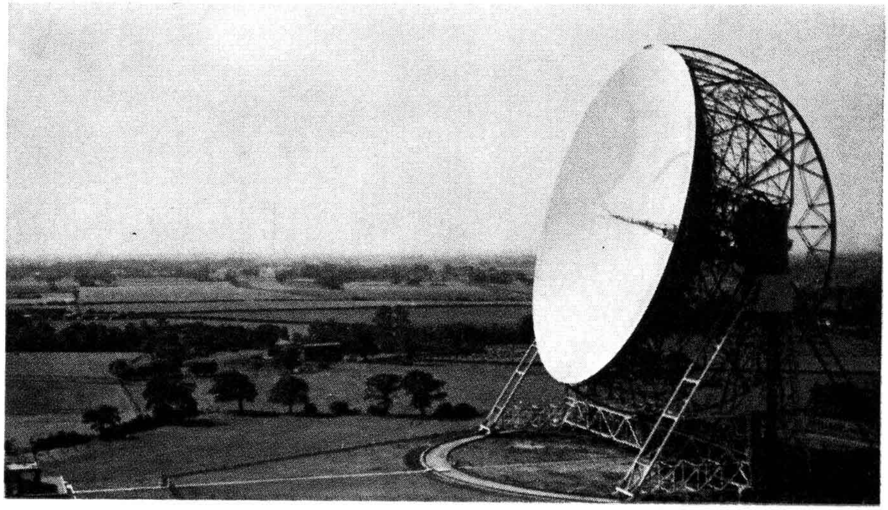
UNIT 4 RESOURCES IN ENERGY

Green plants capture and store in matter the energy of the sun. All living things use this stored energy for their life activities. Man, as scientist, has learned to convert different forms of energy (heat, light, electrical, mechanical, nuclear) into other forms and use them to do his work. Although he converts energy into other forms, the total amount of matter and energy in the universe remains unchanged.



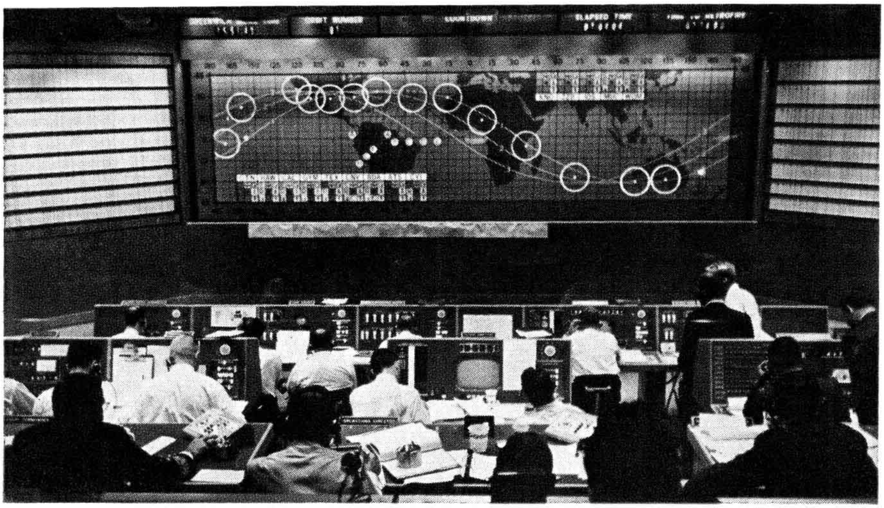
UNIT 5 ENERGY AND WORK

Work is the moving of matter through a distance. A force, supplied by some form of energy, must be applied. Man could do only a given amount of work in a given time by muscles alone, so he invented machines and engines to ease his work. Then he searched for new sources of power. In all his searchings, he came to know that energy had to be applied to move objects a certain distance.



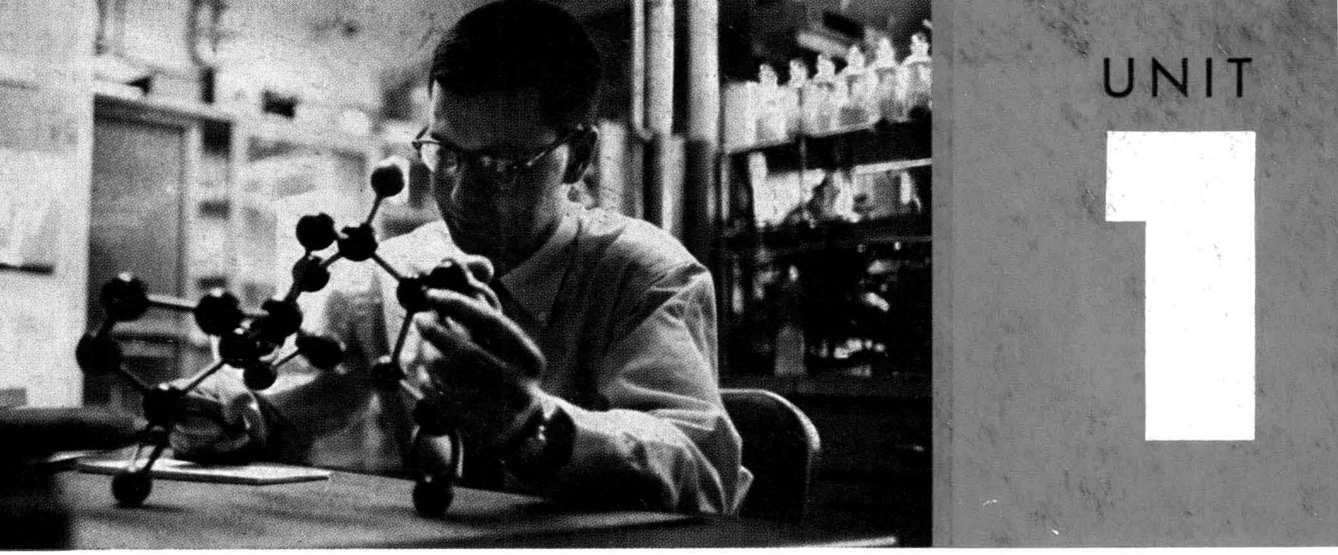
UNIT 6 ENERGY IN VIBRATIONS AND RADIATIONS

The ear of man is sensitive to vibrating objects and his eye to radiations from a light source. Vibrations and radiations are forms of energy produced by physical and chemical changes in matter. Some vibrations are unheard and some radiations are not visible, but always some form of energy is changed into another form. The total amount of energy, however, is not changed.



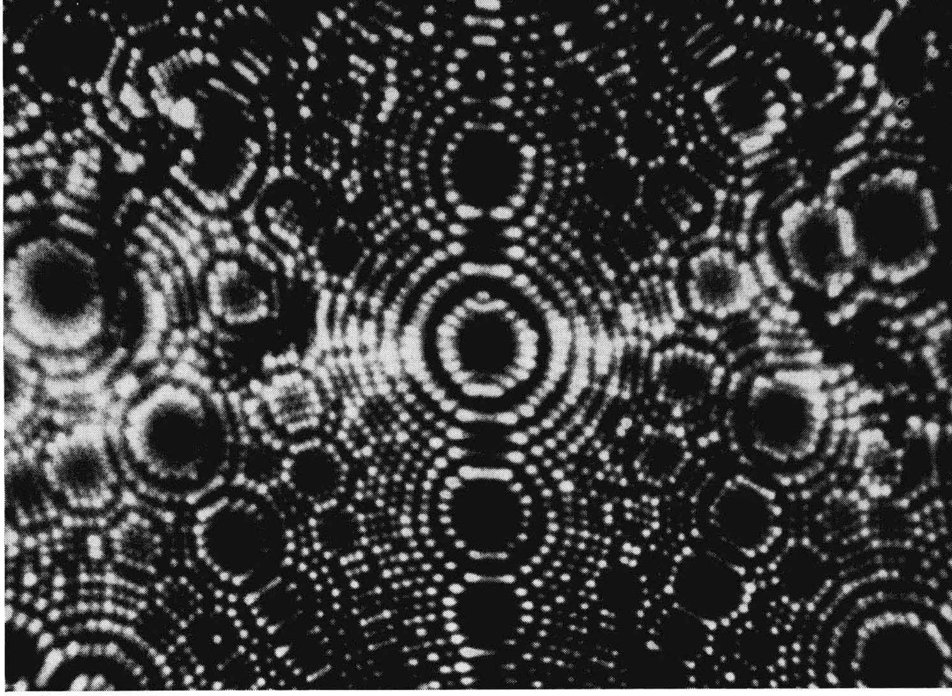
UNIT 7 THE CONQUEST OF SPACE

Beyond the earth are great bodies of matter that make up the planets and stars of the Milky Way and other galaxies in the universe. Early exploration of space resulted in the knowledge that a body at rest remains at rest and once in motion remains in motion unless acted upon by an unbalanced force. Precise knowledge of matter-energy relationships and of energy conversion has made possible manned exploration of space.



4. The lightest known element is (a) oxygen, (b) helium, (c) hydrogen, (d) lithium.
5. Within an atom the particle having a positive charge is the (a) proton, (b) neutron, (c) nucleus, (d) electron.
6. When one teaspoonful of salt is added to one teaspoonful of sugar, the result is a (a) mixture, (b) chemical change, (c) compound, (d) solution.
7. A chemical combination occurs when (a) wood burns, (b) ice melts, (c) water boils, (d) sugar dissolves.
8. Organic compounds such as sugar, milk, and alcohol are similar in that they all contain (a) iron, (b) carbon, (c) an acid, (d) a base.
9. The first important man-made fiber was (a) silk, (b) wool, (c) linen, (d) rayon.
10. An essential compound made of two elements dangerous to handle is (a) salt, (b) sugar, (c) starch, (d) vinegar.
11. All the following are examples of new materials made by chemists except (a) ACTH, (b) alloys, (c) petroleum, (d) plastics.
12. Energy can be obtained from an atom by splitting its (a) electrons, (b) protons, (c) nucleus, (d) neutrons.

Now begin with the first chapter. It will help you to investigate the matter around you and to determine some of the changes it undergoes. The chapter should also give you more knowledge to help you understand even better how matter becomes more useful by being changed.



CHAPTER 1

THE STRUCTURE OF MATTER

The world we live in seems to be made of kinds and forms of matter that we can observe with our senses. Yet all these kinds are made of molecules, tiny units of matter so small we cannot "see" them. These in turn are made of one or more smaller units "called" atoms. The atoms in the bit of platinum above are magnified more than three and a half million times. How very small are the building blocks of which all matter is made!

Let us imagine that we have a tiny drop of water before us and we divide it into halves, into quarters, into sixteenths, and so on. If we could divide this drop of water into smaller and smaller particles, sooner or later the particle would be so small that it couldn't possibly be any smaller *and still be a particle of water*. Such a particle would be one **molecule** of water.

How small are these molecules of water? One mathematician estimated that if the molecules of water in one test tube of water were all suddenly enlarged to the size of a grain of sand, there would be enough water from this original tubeful to cover the entire earth with an ocean six miles deep.

Another mathematician gave this interesting description of the size of molecules: If a test tube of red dye (a substance made up of molecules) were poured into the ocean and allowed to spread through all the oceans of the world, a glass of ocean water taken years later from any place in any of the five oceans would still contain over a million molecules of this same red dye. Imagine how many molecules there must have been in the original test tube of red dye, and how small they had to be to fit into one test tube!

What would happen, then, if we tried to break molecules of water into still smaller particles? We can actually do this by passing an electric current through water.

1. INVESTIGATING A MOLECULE

Your school laboratory probably has a piece of apparatus like the one shown in Fig. 1-1.

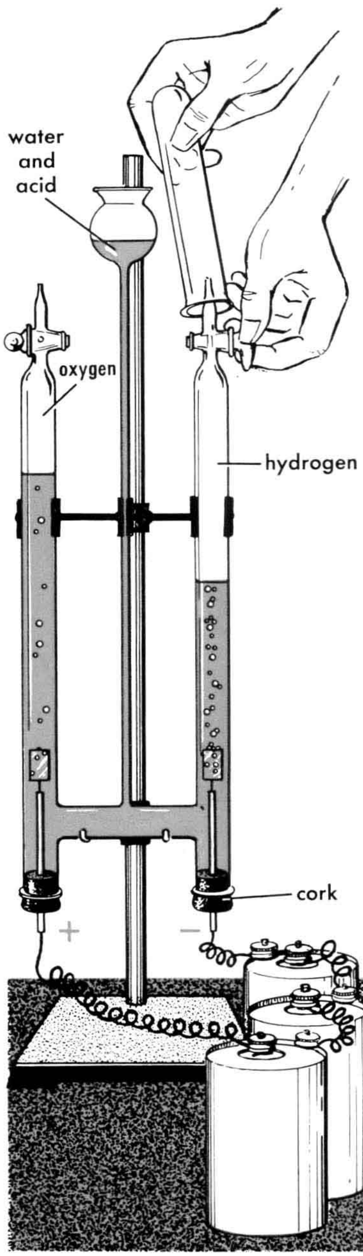
Fill the apparatus with water, and add a little dilute sulfuric acid. The acid makes the water able to conduct an electric current. Place a chalk mark on the center bulb to mark the level of the liquid at the start of the work. Connect the apparatus to two or three dry cells as shown in Fig. 1-1. Note the bubbles of gas rising in each tube. After the electricity has been on a while, notice that the level of water is falling twice as fast in one of the tubes as in the other. What is happening?

When the lower water level is about 6 inches from the top of the tube, disconnect the dry cells from the apparatus. Hold a test tube over the tube that has the lower water level and slowly open the tube. Quickly close the tube so that the liquid does not escape. Gas rushes upward into the test tube. Test this gas with a burning wooden splint (Fig. 1-2). A small explosion occurs, showing that the gas in the test tube is hydrogen. (When flame touches a mixture of hydrogen and air, the mixture explodes.)

Now without losing any of the liquid, collect the gas from the other tube and test it with a *glowing* wooden splint. Does the splint burst into flame? This shows that the gas collected is oxygen. Oxygen is the gas in the air which supports burning, and a splint will burn more brightly in pure oxygen than in air (which is a mixture of gases with about 20 per cent oxygen). Examine the chalk mark you placed on the center bulb. Has some of the water disappeared? What happened to the water?

The electric current that passed through the water broke the water molecules apart. The water therefore disappeared, and in its place two gases appeared: hydrogen and oxygen. Twice as much hydrogen by volume appeared as oxygen.

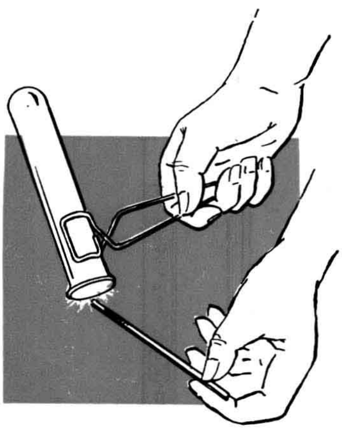
Elements and compounds. Further investigation into the structure of water shows that water is a **compound** made up of two parts hydrogen and one part oxygen. The smallest particle of water that can



1-1 An electric current breaks up water (to which a little sulfuric acid has been added) into two gases: hydrogen and oxygen. How does the volume of hydrogen formed compare with the volume of oxygen?

exist and still be water is a molecule. Neither the hydrogen nor the oxygen which was obtained from the molecule of water can be broken down chemically into other substances. The smallest particle of hydrogen is still hydrogen, and the smallest particle of oxygen is still oxygen. A substance that cannot be broken down chemically into other substances is an **element.** So hydrogen and oxygen are elements. Water is a compound.

The smallest particle of any substance is a molecule of that substance. If the substance is a compound, the molecule consists of two or more particles of *different* elements. If the substance is an element, the molecule consists of one or more particles of the *same* element. These particles making up the molecules are called **atoms.** In an element, all the atoms are of one kind; in a compound, the atoms are of two or more kinds. Thus a molecule of water consists of two separate atoms of hydrogen and one atom of oxygen. Water is therefore written H_2O. Oxygen in the air exists as a molecule, and is written O_2, which means two atoms of oxygen joined together. Hydrogen and nitrogen are two other gases that exist under ordinary conditions as molecules having two atoms. They are written H_2 and N_2. In the formula for water (H_2O), two atoms of hydrogen are shown combined with one atom of oxygen. The H_2 in the formula for water does not refer to a molecule of hydrogen. Helium, however, is a gas whose molecules consist of only one atom. It is written He. Other examples of elements whose molecules consist of only one atom are krypton, neon, argon, and xenon (ZEE–non). All of these are very rare gases making up less than 1 per cent of the air.



1-2 A burning splint, a test tube of a gas, the "pop" of a small explosion. For what gas is this a test?

There are more than 100 elements, most of which are found in the earth and the earth's atmosphere. Here is a list of some familiar natural elements:

aluminum	iodine	potassium
calcium	iron	radium
carbon	lead	silver
chlorine	magnesium	sodium
copper	mercury	sulfur
gold	nitrogen	tin
helium	oxygen	uranium
hydrogen	phosphorus	zinc

Of the natural elements, hydrogen is the lightest and simplest, and uranium the heaviest and most complex. In addition to the elements found in nature, there are others that have been made by man during atomic energy research. At present, eleven elements more complex than uranium have been man-made, making a total of 103 elements, but by the time you read this book, scientists may have prepared even more.*

CHECK YOUR UNDERSTANDING

1. How can we test for the presence of hydrogen gas? oxygen gas?
2. What part of the air we breathe is oxygen?
3. Describe how water molecules can be broken down into simpler particles.
4. What is the difference between an element and a compound?
5. What is a molecule? an atom? Is a molecule ever an atom? Explain.
6. Which is the lightest element? the heaviest?
7. How many different elements are found in nature?

THINK IT OVER

1. Iron is an element. What is rust?
2. How are the elements similar to the twenty-six letters in our alphabet?

INVESTIGATE

Breaking molecules. A molecule of hydrogen peroxide contains the same two elements as water, namely, hydrogen and oxygen. In a molecule of hydrogen peroxide, two atoms of hydrogen are bonded with *two* atoms of oxygen. The formula is H_2O_2.

Place some manganese dioxide in a bottle. Manganese dioxide will speed up the reaction. You will learn more about this action in Chapter 2.

Insert a two-holed rubber stopper in the bottle. Into one hole, place a thistle tube. Place a bent glass delivery tube in the other hole of the stopper. (CAUTION: To avoid breakage, you will need to moisten the outside of the tubes first. If the tubes do not go into the stopper easily, ask for help from your teacher.) Collect the gas as shown in Fig. 1-9.

Add hydrogen peroxide to the first bottle through the thistle tube. In the presence of manganese dioxide, the hydrogen peroxide molecules break apart more rapidly into water (H_2O) and oxygen.

Test the gas collected by lighting a wooden splint, blowing out the flame, and inserting the glowing end into the bottle. What happens? What gas was collected?

2. ATOMS AND THEIR STRUCTURE

Although the smallest part of a substance that can still exist as that substance is a molecule, many scientists are concerned with studying the particles that make up the molecule. These particles, as you know, are atoms. Atoms may be thought of as the building blocks of which the molecules of elements and compounds are made.

* These eleven man-made elements are: neptunium, plutonium, americium, curium, berkelium, californium, einsteinium, fermium, mendelevium, nobelium, and lawrencium.

Atoms, closely grouped or joined together (chemically combined), may make up the molecules of the gold in a ring, the air you breathe, the water you drink—even the food you eat. A desk, the paper in this book, and even the print on the pages are made up of atoms. These atoms make up the molecules in these substances.

It is perfectly correct to think of atoms as building blocks, so long as you realize that these building blocks make up molecules of substances. Even you are made up of atoms. The smallest living part of you is a **cell.** This living cell, however, is made up of molecules that, in turn, are made up of several kinds of atoms. These atoms are chemically combined in special ways.

All matter occupies space and has weight. Since an atom is a bit of matter, what is its weight? It must be very, very small indeed. In fact, to describe the weight of an atom in grams,* one would need to write a decimal point followed by about twenty zeros before writing a number. Such small weights are difficult to imagine. Scientists, however, are more interested in knowing whether one atom is heavier than another than in knowing the exact weight of each kind of atom. They are more interested in **relative weights;** that is, in knowing how much heavier one atom is than another.

1-3 Marie Curie with some of her laboratory equipment. She and her husband Pierre discovered radium in 1898.

If you were to weigh a quantity of aluminum and compare it with the weight of the same quantity of gold, the aluminum would be lighter than the gold. An aluminum atom would be lighter, would weigh less, than a gold atom. In the same way, it can be established that an oxygen atom weighs less than a lead atom and a carbon atom less than an oxygen atom.

By weighing atoms carefully in special ways, scientists have found that an atom of hydrogen weighs less than an atom of any other element. An atom of oxygen, for example, is about 16 times as heavy as an atom of hydrogen. An atom of gold is about 197 times as heavy as an atom of hydrogen. An atom of carbon is about 12 times as heavy as an atom of hydrogen; that is, a carbon atom has a relative weight of 12 in comparison with a hydrogen atom. Nowadays scientists figure relative weights by comparing the weight of the atoms of other elements with that of the carbon atom, which has a weight of 12. In relation to carbon, hydrogen has a weight of about 1; hence, you can think of relative atomic weights as given in relation to hydrogen, even though the carbon atom is used as the base for comparison in arriving at the weight of atoms. Thus an atomic weight of 16 (the weight of oxygen) means that an atom of oxygen has a weight 16 times that of an atom of hydrogen.

* About 454 grams equal 1 pound. The gram is the commonly used unit for indicating in the metric system the weight of an amount of a substance.