CLASSIC LIVING BOOK

MATTER, MOLECULES, & ATOMS

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COMPLETE AND UNABRIDGED

Matter, Molecules, and Atoms

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LIVING BOOK PRESS


100%
VIRGIN WOOL
ONE OUNCE
Butter
RED INK
Sugar
Sugar

MATTER, MOLECULES, AND ATOMS

FOURTEEN different materials are pictured on page 2. It is not at all hard to tell these materials apart, for each one has certain characteristics, or properties; which make it unlike the others. Loaf sugar, for example, is hard, white, and sweet; it has no smell; it does not melt easily; it does dissolve easily in water. No other material pictured has this same combination of properties.

But, although each of the materials has properties of its own, all fourteen are alike in two ways: They all take up space. They all have weight.

All materials are alike in these same two ways. In fact, we define a material by saying that it is something which takes up space and has weight. Heat is not a material—it does not take up any space or weigh anything. Light is not a material—you could not measure it by the pint or the pound. Sound, radio waves, electric currents, and gravity are not materials, either.

It is easy to see that all the materials in the picture take up space. No one would expect to be able to pour milk into a glass already full of lemonade or to put an ice cube into the space occupied by a block of wood. It is not so easy to see that some materials—air, for example—take up space, but there are ways, some of which you will find later, of showing that they do.

Butter, sugar, and some of the other materials pictured are sold by the pound—it is clear that they weigh something. No one buys silk cloth or lemonade by the pound, but simply lifting these materials tells you that they have weight. In the case of air and some other materials, however, people were long in discovering that they, too, have weight.

All materials taken together may be spoken of as *matter*. We can now say, then, that every kind of matter takes up space and has weight.

SOLIDS, LIQUIDS, AND GASES

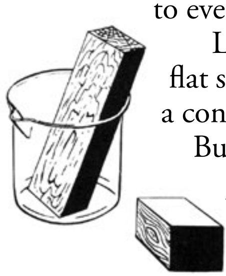
The materials pictured on page 2, although they can be told apart easily, can be grouped together in different ways. An important way in which some of them are different from the others is that some are solids while others are liquids. You do not have to be told that the milk, red ink, and lemonade are the liquids. The others are all solids.

A piece of any solid has a definite shape. A block of wood, for example, is the same shape whether it is on a table, in a beaker, or anywhere else. Of course, the shape of the block of wood could be changed. It could be carved into the figure of an animal. It could be ground into sawdust. It could be split into long, thin pieces. But it keeps its shape until something forces it into a different shape. And in some cases it takes a great deal of force to change the shape of a piece of solid material. Can you imagine tearing a silver dollar in two with your hands?

A piece of a solid material also has a size of its own. For this reason it is possible to buy 4 yards of silk cloth, or 2 square feet of copper, or wooden timbers 2 inches by 4 inches by 20 feet. There is no chance that a block of wood resting in a beaker will spread outward and upward to fill the whole beaker. There is no chance that piling other similar blocks on top of it will squeeze it into a much smaller space.

Solids do not, as many people think, have to be hard. Wool and silk and modeling clay are not hard, but they are solids. They are solids because they have a size and shape of their own.

Some solids occur in the form of beautifully shaped crystals. Quartz, for example, occurs in six-sided crystals that come to points at the ends. Snow crystals, with their six points, are well known to everyone.



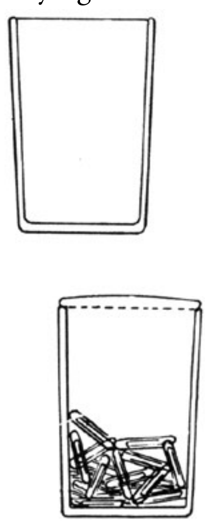
Liquids do not have any definite shape. On a flat surface a liquid spreads out over the surface. In a container it takes the shape of the container.

But liquids do have a definite size. A quart of milk poured into another quart bottle will just fill it. Poured into a half-gallon bottle it will fill it exactly half full.

Probably, when you were thinking of which of the materials on page 2 were liquids and which solids, the question you asked yourself was: Which ones can be poured? All liquids can be poured. But of course sand and granulated sugar and flour can be poured, and they are solids. At first glance, it seems, moreover, that they have no shape of their own. Granulated sugar, if poured into a cup, will spread out to take the shape of the cup. But really the separate tiny little pieces of sugar—and of sand and of flour—have a shape of their own.

Most liquids are wet; that is, if you put your finger or a piece of paper into one, enough of the liquid would stick to your finger or the paper to make it wet. But there are exceptions. The liquid mercury, although it can be poured like water and although it takes the shape of a container just as water does, is not wet. If you stick your finger or a piece of paper into a bottle of mercury, it is just as dry as before.

The sketch below shows a surprising characteristic of liquids. In the experiment pictured, paper clips are dropped one at a time into a tumbler level full of water. More than a hundred clips can usually be dropped in before any water runs over the edge of the tumbler. Instead of overflowing, the water piles up. It acts very much as if there were a thin skin over the top. This characteristic of liquids is called *surface tension*. Perhaps you have heard of carrying water in a sieve. This is sometimes possible because of surface tension. It is sometimes possible, moreover, to make a needle float on water even though steel is heavier than water. Surface tension may keep it from sinking. Mercury shows surface tension even more clearly than water. Small bits of mercury are ball-shaped because of it.



Although all the materials pictured on page 2 are either solids or liquids, not all materials will fit into these two groups. Air is one that will not. Carbon dioxide, stove gas, hydrogen, and oxygen are others that will not. These materials are gases.

The left-hand picture on page 6 shows a way of making clear that air takes up space. The flask into which the boy is trying to pour colored water

looks empty but is really full of air. The air in the flask is holding the water out.

Gases have no shape of their own. It is ridiculous to think of making air into a model of a little animal. Gases take the shape of any container they are in. It is hard to see that they do, because most gases are invisible. There are, however, some colored gases that we can see. Various tests show that invisible gases take the shape of the containers they are in just as these colored gases do.

The right-hand picture at the top of the page also shows that air takes up space. It shows, too, another characteristic of air. The tumbler was full of air to begin with; and it was pushed straight down so that none of the air could escape. But there is now some water in the tumbler. The air has been squeezed into a smaller space.

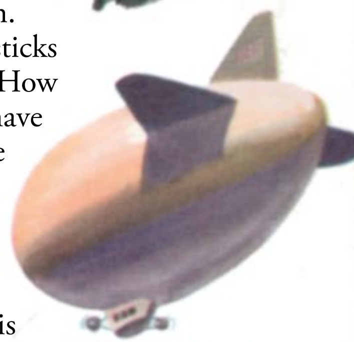
A gas, unlike both liquids and solids, actually has no size of its own. If a quart bottle full of air were emptied into a really empty half-gallon bottle, the air would spread outward and upward to fill the whole space. Similarly, even if a space is full of air, a great deal more air can be squeezed into it. You see this happen with automobile tires all the time. Even though a tire is full of air, more air can be pumped in.

Every material is a liquid, a gas, or a solid. It is now clear that you have only two questions to ask about any material to find out which it is: Does it have a shape of its own? Does it have a size of its own? If the answer is yes to both of these questions, the material is a solid. If the answer is no to the first and yes to the second, the material is a liquid. If the answer is no to both, the material is a gas.

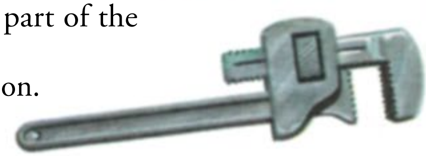
EIGHT COMMON ELEMENTS

Some elements are much more abundant than others. The sketches at the right suggest eight of the most common: carbon, aluminum, oxygen, hydrogen, iron, sulfur, silicon, and nitrogen.

The top picture on page 19 shows black sticks of carbon. But diamonds are carbon, too. How hard it is to believe that any element could have such different forms! The differences come from the fact that diamonds are crystals of carbon while the carbon of the sticks is not in crystals.



Without carbon we could not live, for every bit of living material in our bodies is made partly of carbon. Carbon is a part of the living material of every living thing.



All our common fuels are part carbon. Hard coal is almost pure carbon. Soft coal, wood, gasoline, kerosene, fuel oil, and cooking gas are largely carbon.

Other rocks besides coal contain carbon. Limestone, for example, is a compound of carbon-calcium carbonate.

On earlier pages you were introduced to several other compounds of carbon. There are, altogether, thousands of carbon compounds. Some, like limestone, are solids. Some are liquids, some gases.

Green plants take carbon dioxide and build it into sugar and starch. Sugar and starch are in many of the foods we eat. There are simple ways of testing for these two carbon compounds.

The right-hand picture on page 27 shows the test for starch. When a drop of iodine is added to anything containing starch, a purple color appears—the sign that starch is present.

The right-hand picture on page 29 shows a test for certain kinds of sugar. Fehling's solution, a mixture of several compounds, is used for the testing. It comes in two parts, A and B. To test a food for sugar, add equal amounts of solutions A and B. Heat the mixture. If an orange color results, sugar is present.

Aluminum is the most abundant of all the metals on earth. Before the nineteenth century, however, no one had ever seen it. It occurs in nature only in compounds. Many rocks and all clays contain it. The finding of a cheap way of separating aluminum from some of its compounds is one of the triumphs of modern science.

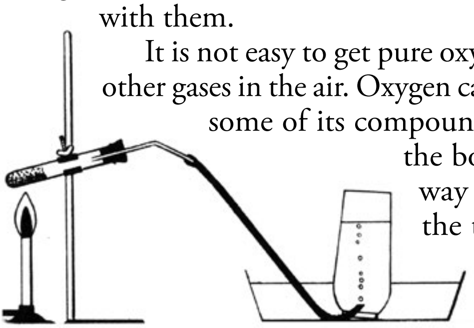
Aluminum has played an important part in the advance of aviation. It is light and does not rust. Aluminum foil and aluminum pans are much used in cooking.

Oxygen is the commonest of all the elements. The air is about one-fifth oxygen. Water, by weight, is eight-ninths oxygen. The oxygen in the earth's crust weighs as much as all the other elements put together. You yourself are more than half oxygen. There is oxygen in almost everything around you.

The oxygen in water, in rocks, and in your body is joined with other elements to form compounds. In air, on the other hand, much of the oxygen is free, that is, not in a compound.

Free oxygen is necessary for burning. For this reason fires must have a constant supply of air. We have to breathe free oxygen in order to live. Otherwise the food we eat cannot burn in our bodies and furnish us with the energy we have to have. Flyers who go high above the earth, where the air is thin, carry tanks of oxygen with them.

It is not easy to get pure oxygen by separating it from the other gases in the air. Oxygen can, however, be obtained from some of its compounds quite easily. The sketch at the bottom of the page shows one way of doing so. The material in the test tube is a mixture of two chemicals: potassium chlorate ($KClO_3$) and manganese



dioxide (MnO_2). Heating the mixture drives off the oxygen from the potassium chlorate. The oxygen bubbles up into the bottle full of water and drives the water out. Hydrogen looks like oxygen—they are both invisible gases—but it has some properties that make it very different from oxygen. It is much lighter than oxygen—in fact, it is the lightest of all known substances. Because of its lightness, hydrogen was once much used in balloons. Now, however, helium is being substituted for it whenever possible, because hydrogen can be set on fire very easily.

There is little free hydrogen on the earth, but there are thousands of hydrogen compounds. It is hydrogen, you remember, which is combined with oxygen to form water. Hydrogen is one of the four most abundant elements in our bodies. It is one of the elements in sugar, starch, and many, many other compounds of carbon. Hydrogen is, moreover, always a part of the chemicals called *acids*.

"Acid" comes from the Latin word for "sour." All acids taste sour when they are weak. Vinegar, lemon juice, green apples, sour cherries, and grapefruit are all sour because they contain acids. And every one of the acids contains hydrogen.

Some acids are very strong. It would not be at all safe to taste them unless they were diluted with a great deal of water. On this page you are shown a safe way of testing for acids. The boy is using litmus paper—paper colored with a special kind of dye. Some litmus paper is pink; some is blue. In acids pink litmus paper stays pink and blue litmus paper turns pink.

Litmus paper can also be used to test for *bases*. Bases are the opposites of acids. In bases pink litmus paper turns blue and blue litmus paper stays blue. Bases always contain both oxygen and hydrogen. In the formula for a base there is always an OH. Lye

(NaOH) is a very strong base. Ammonium hydroxide (NH_4OH), formed when ammonia is dissolved in water, is a weak base.

Next to aluminum, iron is the most abundant metal. Thousands of years ago men found how to get iron rather easily from some of its ores. They began making tools of it. Later they learned to make it into steel. Much of the world's industry today depends on this metal.

The left-hand picture on page 29 shows four of the compounds in which iron occurs. Notice the different colors of the different compounds. They help you understand how hard it is to guess, from the look of a material, what elements it is made of. The grayish-black material is magnetite (Fe_3O_4), the red material, hematite (Fe_2O_3), the green, iron sulfate ($FeSO_4$), and the yellow, iron chloride ($FeCl_2$).

Sulfur is one of the elements pictured on page 19. Usually, as in the picture, sulfur is a yellow powder. It may be in the form of yellow crystals instead. It may also be a dark-brown rubbery substance. It can disguise itself just as carbon can.

You have already met two compounds of sulfur: copper sulfate and sulfuric acid. Sulfuric acid is the most important sulfur compound. It has many uses, among them making ammunition and fertilizer and getting gasoline from petroleum. This acid is sometimes called "the king of chemicals."

Sulfur itself used to be called burning stone, or brimstone, because it catches fire very easily. Because it is easy to set on fire it is used in making matches. Sulfur is also used in manufacturing things of rubber. Rubber was of very little importance until the discovery was made that sulfur could be used to keep it from being sticky in warm weather and stiff in cold weather. Then a great many uses—as a material for automobile tires, for example—were found for it.

Silicon is, next to oxygen, the most abundant element on earth. But you are almost sure never to have seen it. It occurs in nature only in compounds, just as aluminum does. You have already found that quartz is a compound of silicon. When you know that sand is made up mostly of tiny bits of quartz, it is clear that silicon is very abundant.

Most glass is made of sand. Glass plays an important part in our lives; silicon therefore does, too. Since the lenses of our glasses are made of glass, silicon may be helping you read this book.

Nitrogen is another element that we could not live without. All living material contains nitrogen just as it contains oxygen and hydrogen. You yourself, then, are part nitrogen.

Nitrogen, like hydrogen and oxygen, is a colorless gas. It is very abundant in the air—more than four-fifths of the air is made of it. The nitrogen our bodies must have in order to build the new living material needed for growth and repair does not, however, come from the air. It comes instead from some of the foods we eat. One reason why we need to eat such foods as milk, eggs, meat, and cheese is that they all contain nitrogen.

Nitrogen is not a very good "joiner." There are not nearly so many compounds of nitrogen as there are compounds of oxygen and hydrogen. Laughing gas, which you may have been given at the dentist's when you had a tooth pulled, is one compound of nitrogen. Nitric acid is another. Nitric acid, like sulfuric acid, is important in industry. Compounds of nitrogen are used in explosives. Explosives play an important part in building roads, mining coal, and other such everyday work as well as in waging war.