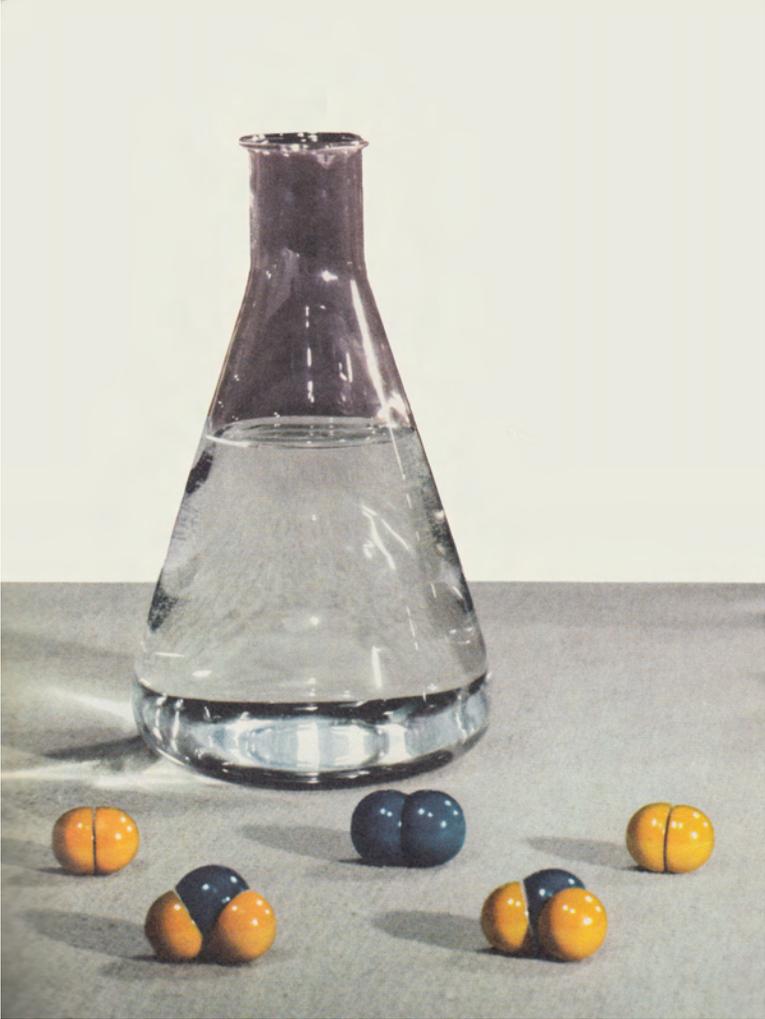


**MATTER, MOLECULES,
AND ATOMS**



The Basic Science Education Series

**MATTER, MOLECULES,
AND ATOMS**

by

Bertha Morris Parker

YESTERDAY'S CLASSICS

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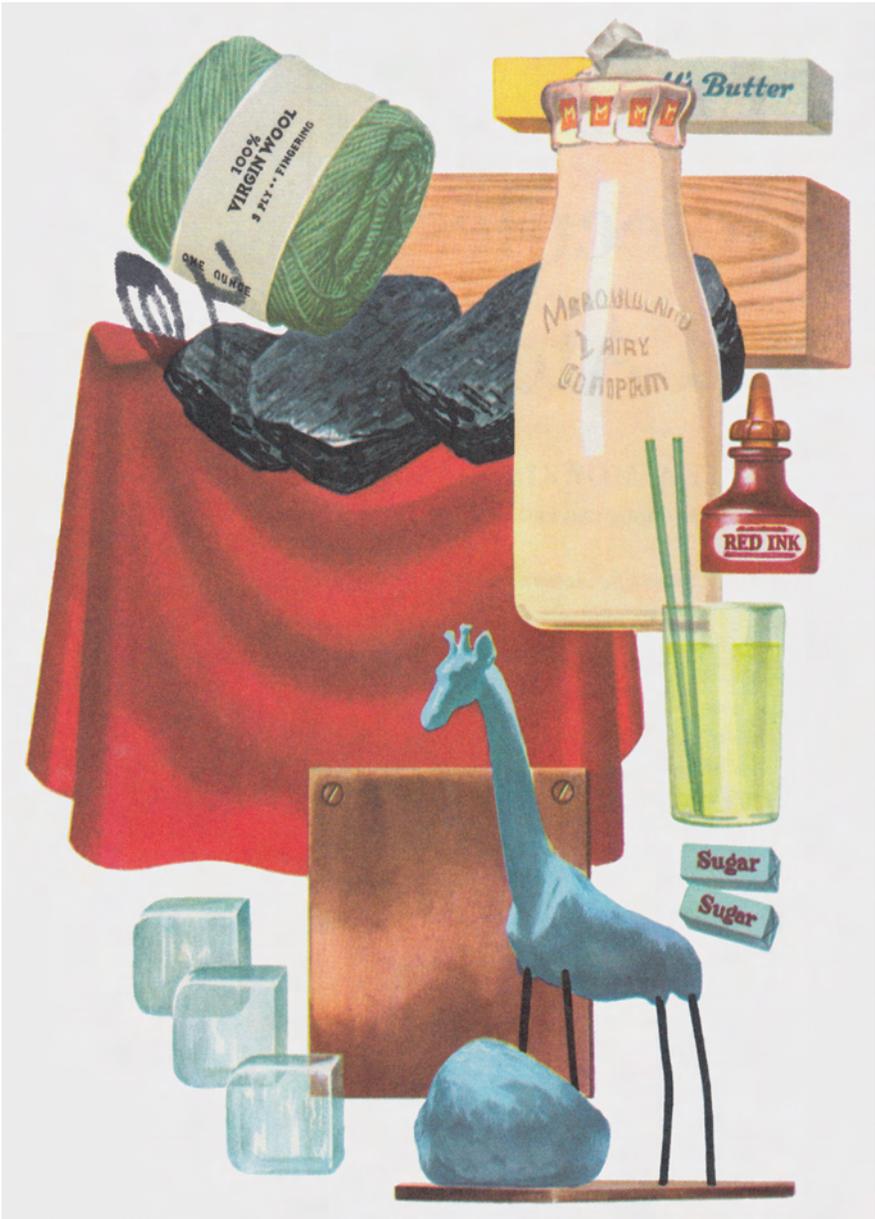
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MATTER, MOLECULES, AND ATOMS

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

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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.

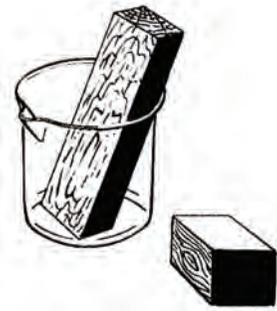
SOLIDS, LIQUIDS, AND GASES

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

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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.

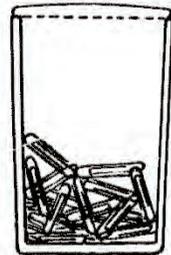
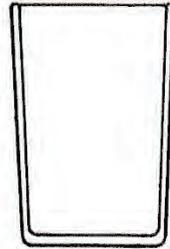
Probably, when you were thinking of which of the materials on page 2 were liquids and which solids, the question you asked yourself was: Which ones can be poured? All liquids can be poured. But of course sand and granulated sugar and flour can be poured, and they are solids. At first glance, it seems, 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

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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.

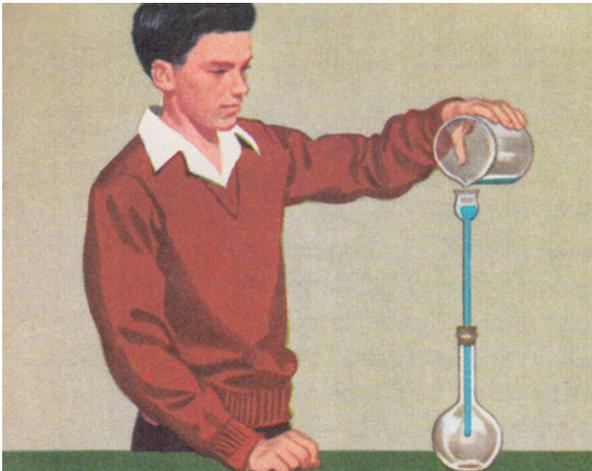
The sketch below shows a surprising characteristic of liquids. In the experiment pictured, paper clips are dropped one at a time into a tumbler level full of water. More than a hundred clips can usually be dropped in before any water runs over the edge of the tumbler. Instead of overflowing, the water 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.



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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.

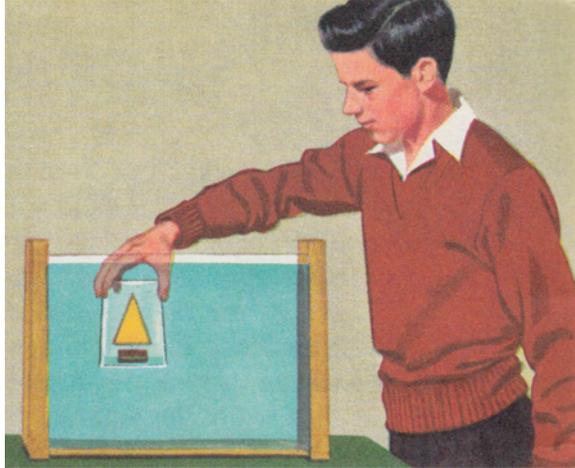
The picture below shows a way of making clear that air takes up space. The flask into which the boy is trying to pour colored water looks empty but is really full of air. The air in the flask is holding the water out.



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 picture at the top of the next 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

SOLIDS, LIQUIDS, AND GASES



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.

CHANGES OF STATE

Matter, you have seen, may be in solid, liquid, or gas form. Another way of saying the same thing is that there are three states of matter: solid, liquid, and gas.

When we say that a material is a solid, a liquid, or a gas, we usually mean that it is so at ordinary temperatures. But it is possible in many cases for gases to become liquids or solids, for liquids to become gases or solids, and for solids to become liquids or gases. Such changes are called *changes of state*.

Of all changes of state those that take place in water are probably most familiar to you. You know that water, a liquid, may change to ice, a solid, or to water vapor, a gas. You have seen ice change to a liquid, and you have seen the water vapor in the air change to drops of water on the outside of a pitcher of cold lemonade. Perhaps you do not know that water vapor can also change directly to a solid and that ice can change to water vapor without becoming a liquid on the way. Snowflakes are crystals of ice formed from water vapor, and in wintertime wet clothes hung out on the line may “freeze dry.”

The changing of a liquid or solid to a gas is called

CHANGES OF STATE

evaporation. The word comes from “vapor,” another word for gas. Some liquids evaporate faster than water. Alcohol, gasoline, and ether are among those that do. Dry ice is one of the solids you may have seen evaporate. It changes to a gas without changing to a liquid on the way. The picture below shows another solid changing to a gas. Crystals of iodine are changing to a violet vapor.



In many cases evaporation takes place merely from the surface of a liquid. But when a liquid is heated rapidly, bubbles of gas may form below the surface and then rise to the surface and break. We say then that the liquid is *boiling*. The water vapor that comes from boiling water has been given the name of “steam.”

The changing of a solid to a liquid is called *melting*. In the picture at the top of the next page, the paraffin of the candle is melting and traveling up the wick. Butter, lard, sugar, iron, copper, and lead are among the other solids that melt.

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The changing of a liquid or a gas to a solid is called *freezing*. Dry ice is made by freezing carbon dioxide, one of the gases in the air. Granite, a common rock, is formed by the freezing of hot, liquid rock from deep in the earth.

The changing of a gas to a liquid is called *condensation*. The changing of a gas to a solid may be called condensation, too, instead of freezing. Thus, when the water vapor of the air changes to snow crystals, we may say either that the water vapor condenses as snow crystals or that it freezes.

In any change of state a transfer of heat takes place. A material freezes or condenses only when it loses heat. Evaporation and melting mean a gain in heat.

Changes of state are of great practical importance. The diagram on the opposite page shows one of the many uses to which we put them. Water is being distilled to rid it of mud and other impurities. The water is first heated

CHANGES OF STATE

to boiling. The steam passes through a condensing tube. There it is cooled by cold water flowing around it and is changed back to water. Since the mud and minerals in the water do not change to gases at the temperature at which water boils, they are left behind.

