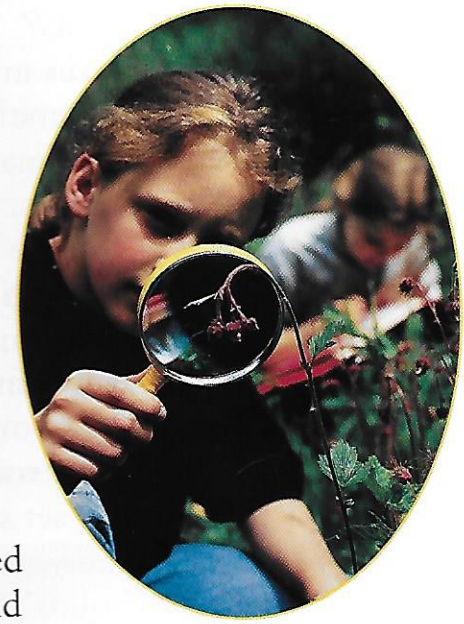
Chapter 1

Classifying Matter

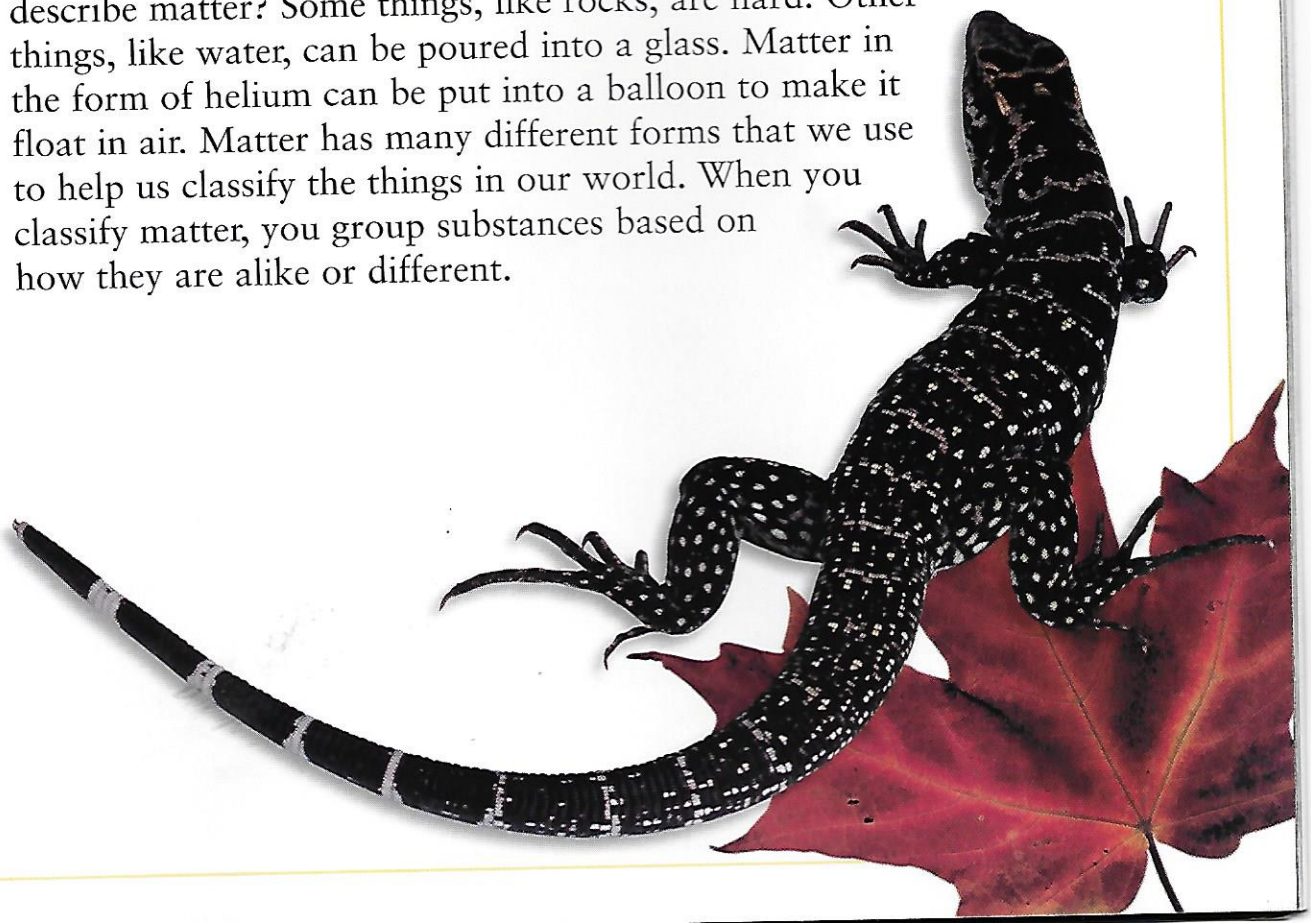
Matter and Its Properties

Butterflies, leaves, lizards, and even you are made of matter. What do you know about matter? Can you describe the matter around you?

You can't escape it! Everywhere you turn, you are surrounded by matter. Some matter, such as the air we breathe, is invisible. The matter that makes up the sun lights up our lives. In fact, even your body is a big bunch of matter.



Look around you. What objects do you see? How would you describe the objects? You might describe some objects by their shape. A ball, a globe, and a marble are all round. You could describe some objects based on their color. For example, many pencils and school buses are yellow. How else could you describe matter? Some things, like rocks, are hard. Other things, like water, can be poured into a glass. Matter in the form of helium can be put into a balloon to make it float in air. Matter has many different forms that we use to help us classify the things in our world. When you classify matter, you group substances based on how they are alike or different.



States of Matter

Because of the differences in matter, scientists have come up with a way of classifying matter based on its form, or **state.**

Solid Matter in its most rigid state is a **solid.** A solid has a definite shape. It also takes up a definite amount of space. Think about a rock. When you look at a rock, you can see that it has a set shape and takes up space. Can you think of other examples of solids?

Liquid Another form of matter is a **liquid.** Like a solid, a liquid takes up a definite amount of space. However, a liquid doesn't have a definite shape. Think about rain. What happens when rain hits the ground? If the rain hits soil, it may go into the ground. If rain falls on a sidewalk, it may form a puddle. If it falls into a glass, it will take the shape of the glass. Liquids are different from solids because liquids change their shape to fit whatever container they are in.

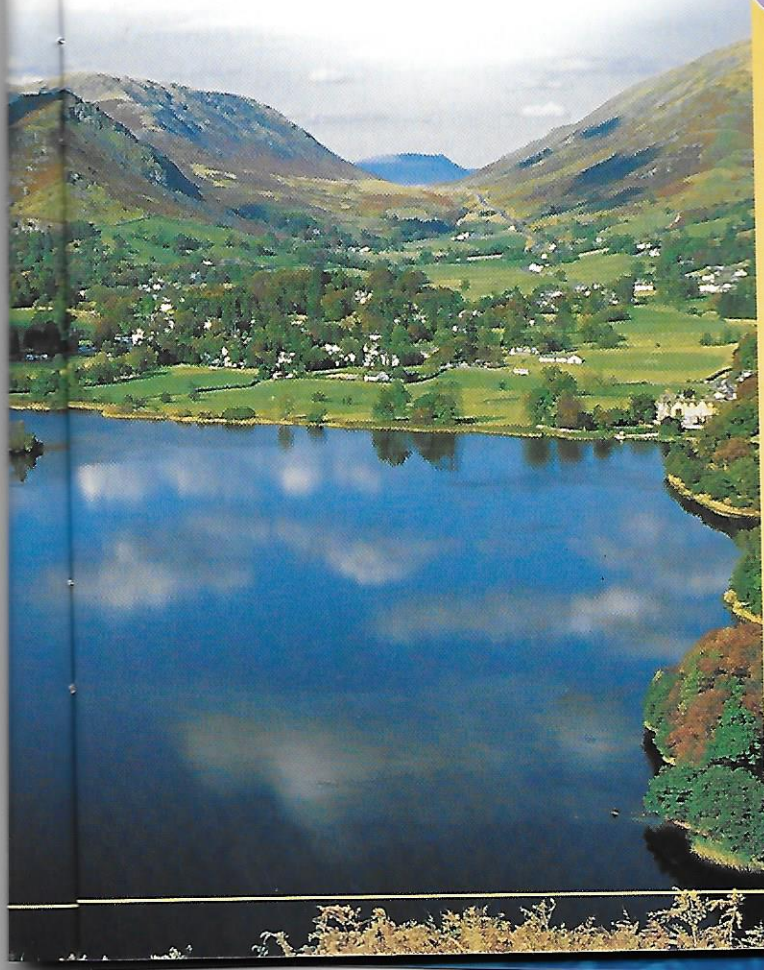
The mountain is a solid. You can see its shape and the amount of space it takes up.

The water in a lake is a liquid. It takes up a definite amount of space, but it doesn't have a definite shape. If you canoed in a lake, the paddles would change the shape of the water.

Gas A **gas** doesn't have a definite shape and doesn't take up a definite amount of space. This means that when a gas enters a container, the gas particles will spread out and fill the container. For example, if you put a small amount of the gas oxygen into a room, the particles of oxygen would spread across the entire room.

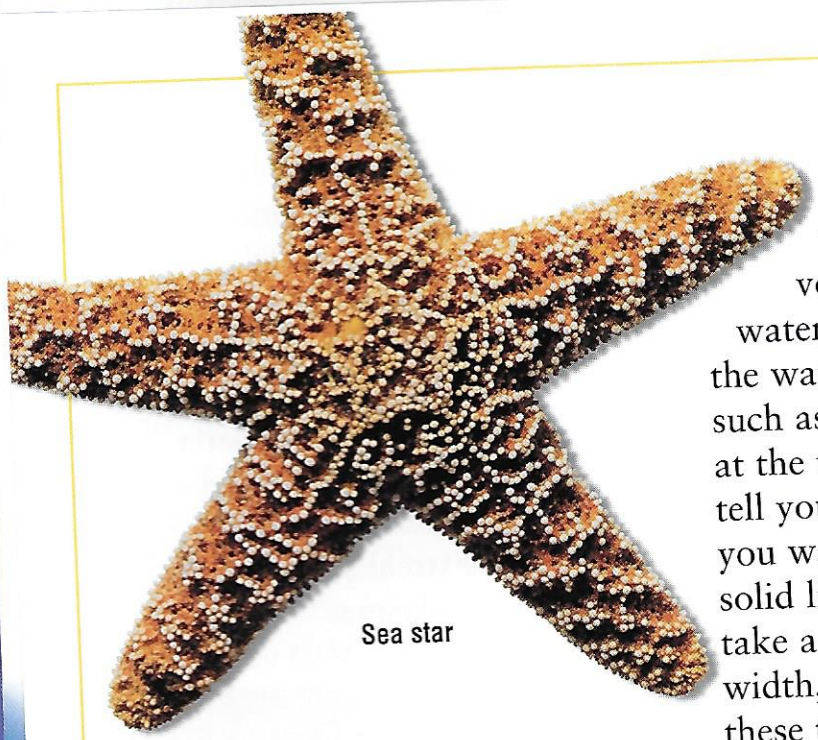
Plasma While most people are familiar with solids, liquids, and gases, there's another state of matter called **plasma.** Plasma rarely occurs naturally on Earth's surface, but the sun and other stars are mostly made of plasma. Plasma is made of electrically charged particles of matter that glow. When you see streaks of lightning, you are seeing plasma.

Air is a gas. It doesn't have a definite shape and doesn't take up a definite amount of space.



Thinking Like a Scientist: Experimenting

When scientists want to test an idea, they conduct an **experiment.** An experiment is a controlled scientific test. Suppose you wanted to find out the temperature at which water changes from a liquid to a solid. You could do an experiment to find out. You would start by making a hypothesis that tells the temperature at which you think water will freeze. Then you would list the materials and the steps of the experiment. Once you do your experiment, you can use the information you gathered to evaluate your hypothesis.



Sea star

Measuring Matter

The different forms of matter help us to classify and describe matter. What are other ways you can describe matter? Look at the sea star. How would you describe it to a friend? You would probably start by telling about its **properties**, such as its color, size, texture, and shape. The characteristics of matter that you can observe are called properties.

All matter has the properties of **mass** and **volume**. Mass is the amount of matter in a substance. You can find the mass of something by putting it on a balance.

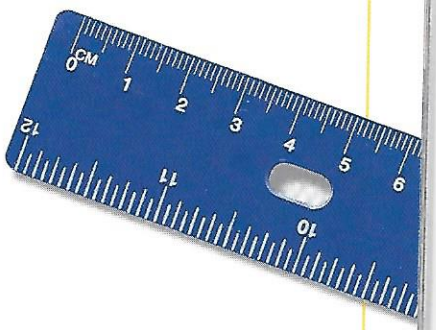
Volume is the amount of space an object takes up. If you want to find the volume of a liquid such as water, all you need to do is pour the water into a measuring device, such as a measuring cup. The mark at the top of the water level will tell you the volume of the water. If you want to find the volume of a solid like a wooden block, you can take a ruler and measure its length, width, and height. Multiplying these three numbers gives you the block's volume. What if you wanted to find the volume of the sea star? Because of its shape, you wouldn't be able to measure the sea star's length or width. The problem of measuring oddly shaped objects was solved by a Greek scientist named Archimedes.

Archimedes' Discovery

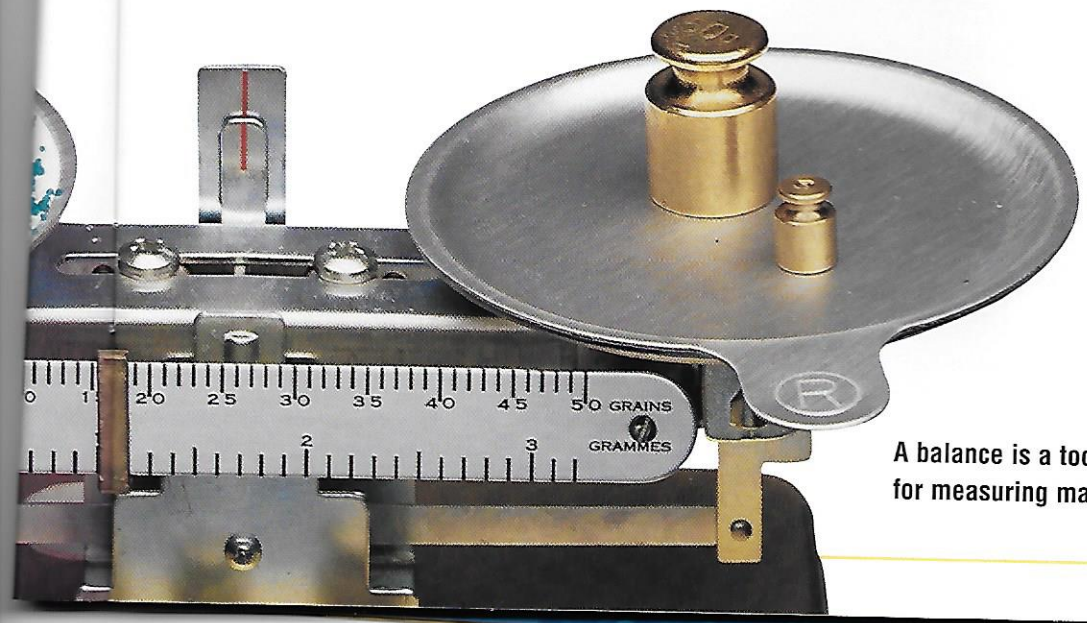
About 250 B.C., Archimedes had to solve a problem for the king. To solve the problem, he had to find the volume of the king's crown. Because the crown had an irregular shape, Archimedes couldn't make the measurement. Then one day he noticed that when he got into the tub, the water level in the tub rose. His body **displaced**, or pushed away, water in the tub. He realized how to find the volume of the crown. He could put it into a container of water and measure how much water it displaced. He could solve the problem for the king!

When you put an object in water, the object displaces the water and makes the water level rise.

What tools can be used to measure the properties of matter?



A ruler is a tool you can use to measure the length, width, and height of an object.



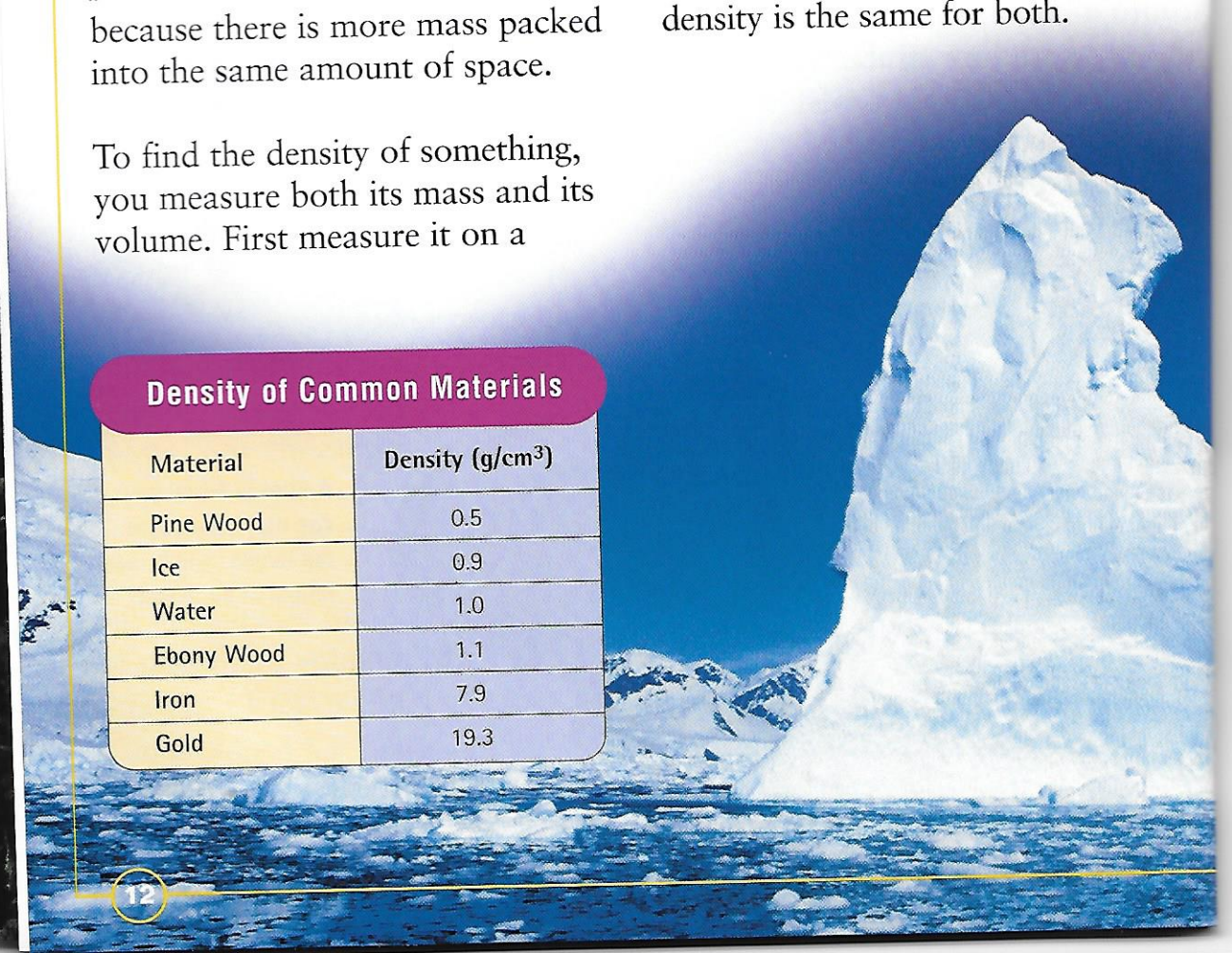
A balance is a tool used for measuring mass.

Discovering Density

In addition to volume and mass, all matter has another property—**density.** Density is the amount of matter in a certain amount of space. In other words, density tells how tightly packed a substance is. For example, imagine that you have two boxes that are exactly the same size. One box is full of sand. It is heavy and has a large mass. The other box is full of feathers. It is light and has a small mass. The box of sand is more dense than the box of feathers because there is more mass packed into the same amount of space.

To find the density of something, you measure both its mass and its volume. First measure it on a balance to get its mass. Then find its volume with a ruler or measuring cup. By dividing the mass by the volume, you'll get the density.

Density is a property of matter that stays the same regardless of how much of a substance you have. It doesn't make a difference if you have a large amount or a small amount of matter. If it's the same kind of matter, the density will be the same for both. For example, both an iceberg and an ice cube are made of ice so the density is the same for both.



Density of Common Materials

Material	Density (g/cm^3)
Pine Wood	0.5
Ice	0.9
Water	1.0
Ebony Wood	1.1
Iron	7.9
Gold	19.3

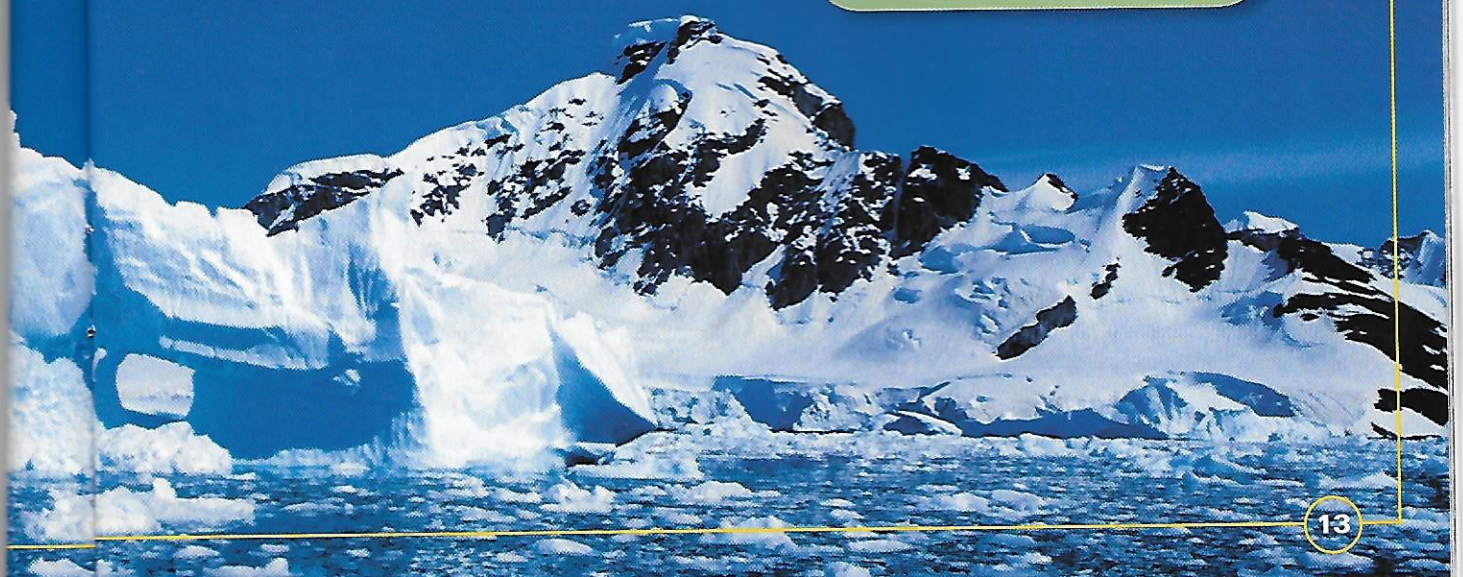
Using densities, we can compare different types of materials. Look at the chart on page 12. You can see that water has a density of about 1 gram per cubic centimeter. Materials that have a density lower than this will naturally float in water.

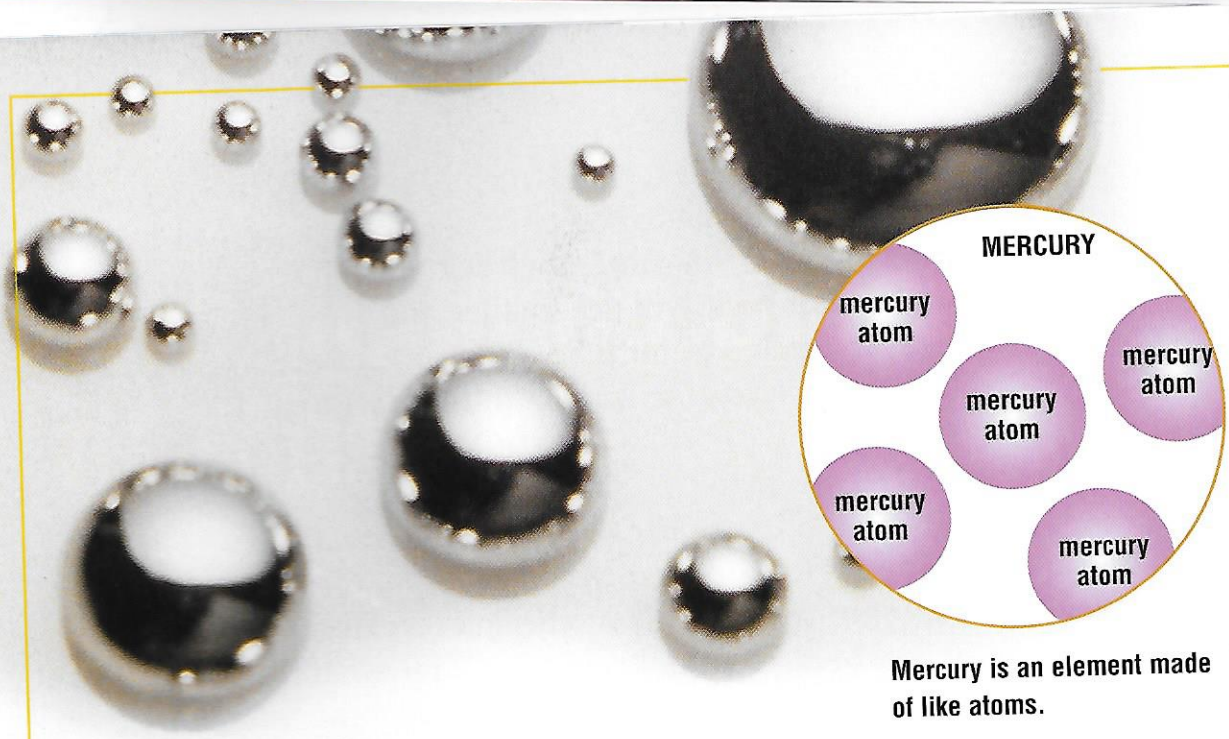
Based on the chart, why would it be better to build a raft out of pine wood rather than ebony wood? The pine raft is less dense than water, so it will float. An ebony raft is more dense than water and more likely to sink.

Did you ever wonder...

... why fish in most lakes don't die when the lakes freeze in the winter?

In some areas, the temperature of winter air gets low enough for the water in lakes to freeze. Most lakes, however, don't freeze all the way through. Just the surface of the water freezes solid. Unlike other substances, water is more dense in a liquid state than in a solid state. As a result, solid water (ice) floats on liquid water. Organisms, such as fish, survive the winter by living in the warmer water below the ice.





Mercury is an element made of like atoms.

Elements and Compounds

From the earliest times, people knew of differences in matter. They learned that metals could be turned into tools and that wood could burn in fire. Around 450 B.C., a Greek philosopher named Empedocles thought about all the different types of matter on Earth. He came up with the idea that all matter was really made up of four basic elements: earth, water, fire, and air.

Later, people began to have different ideas about what elements make up matter. Dalton thought that matter was made of many different elements. He also thought each element was made of a unique type of atom.

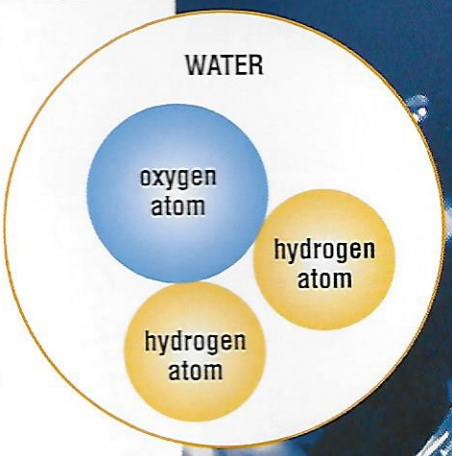
Today scientists define an **element** as a substance that is made of only one kind of atom. Instead of only four elements, today scientists know of more than a hundred different elements. Each element is made of atoms that are all alike. The atoms and the properties of one element are different from the atoms and properties of other elements.

Everything in our world is made of atoms. Some things, like the element mercury, are made of atoms that are all alike. Other things, like water, are made of different kinds of atoms. Substances such as water are called **compounds**.

A compound is a substance that is formed when two or more different kinds of atoms chemically bond to each other. Most of the things in our world are compounds—from rocks to some of the gases in air.

When atoms bond to each other, a **molecule** is formed. A molecule can be made of like or unlike atoms. For example, most of the oxygen in air is found as molecules. Each oxygen molecule is made of two oxygen atoms. A molecule of water is made of one oxygen atom and two hydrogen atoms. So, a molecule of oxygen is made of one type of atom and a molecule of water is made of more than one type of atom.

How are elements different from compounds?



Water is a compound made of different kinds of atoms—one atom of oxygen and two atoms of hydrogen.

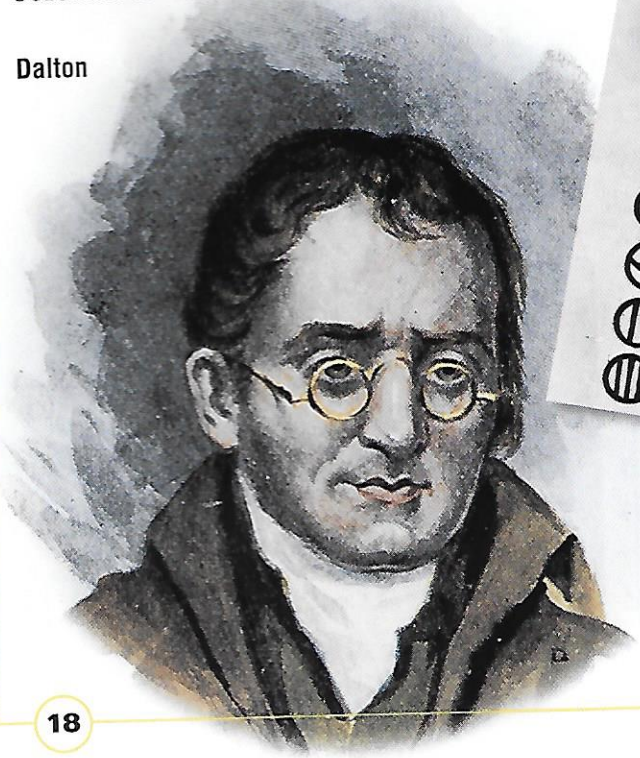
Word Power

In language class the word *compound* often refers to a word made of two or more words that are joined together, such as *rowboat* or *firetruck*. In chemistry a compound is a substance made of two or more kinds of atoms that chemically join together.

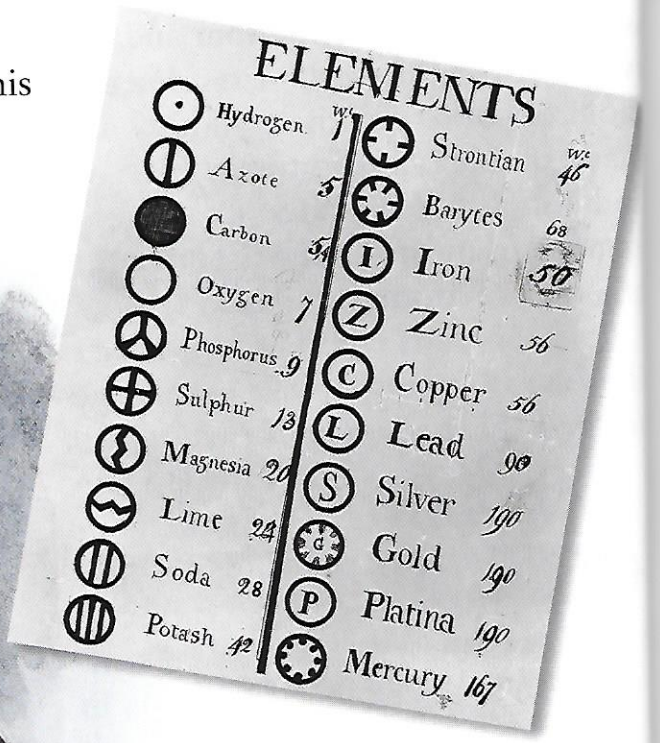
Organizing the Elements

As more and more elements were discovered, scientists tried to organize the elements. When Dalton was experimenting with elements, he organized the elements by their weight. He made careful measurements of each element. Then he calculated the weight of an atom of each element by comparing it with the weight of an atom of the element hydrogen. He listed different elements and showed each of their atomic weights. Many of Dalton's calculations were corrected by later scientists, but his work provided important information that helped other scientists sort out the elements.

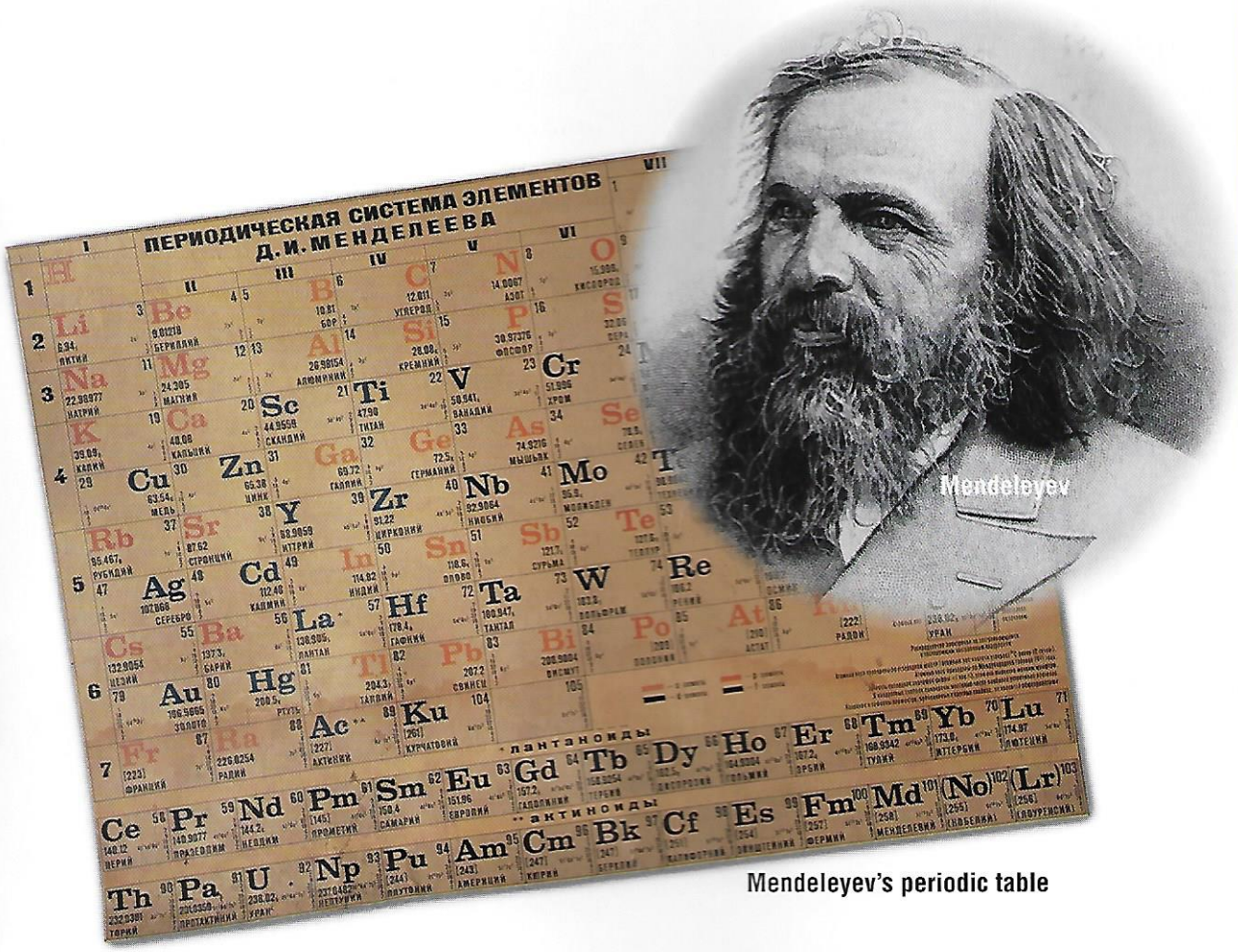
A Russian chemist named Dmitry Mendeleyev came up with a way to organize the elements that is still used by scientists today. He grouped the elements according to their properties and masses. In 1871 he published his **periodic table**. A periodic table is a chart that organizes the elements. Mendeleyev's periodic table grouped elements based on their properties and listed them in order of their atomic masses.



Dalton



Dalton's list of the elements and their atomic weights



Mendeleyev's periodic table

When Mendeleyev made his periodic table, only 63 elements were known. He left spaces on the table where he thought elements that hadn't yet been discovered should be. He was even able to predict the properties of some missing elements. In time other chemists were able to find the missing elements and fill in the blanks.

Today there are more than 112 elements listed on the periodic table. Each element has a name and a symbol that is used to represent the element. For example, the symbol for carbon is C and the symbol for copper is Cu. These symbols, along with atomic masses and other information about the elements, are shown on the periodic table of the elements.

Chapter 3

A World of Change

Changes in Matter

Have you ever gone to sleep on a cold and rainy night and awakened to an ice-covered neighborhood? Did the trees on your street look like they were made of glass? How could this happen?

This amazing change in your neighborhood happened due to a change of matter. As you slept, the temperature of the air went down and caused the rain to freeze. The rainwater that covered everything on your street changed states and turned from a liquid into a solid.

What would happen to the ice on the trees when the temperature got high enough for the ice to melt? Yes, that's right. The water would change states again, going from a solid to a liquid state as the ice melts. If the sun warmed the water enough, the water on the trees or in puddles could change from a liquid to a gas. These are just a few of the many ways in which matter can change.

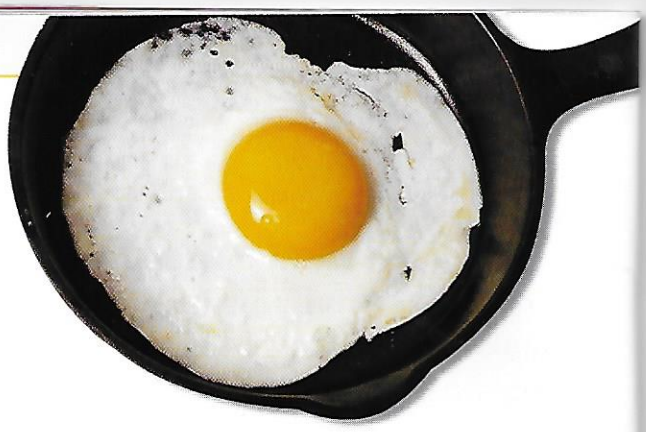
Physical Changes

The type of change that happened as the rainwater changed states is called a **physical change**. A physical change happens when matter changes from one form to another without becoming a new substance. A physical change involves an exchange of energy. For a piece of ice to melt, the ice has to gain heat. For water to freeze, the water has to lose heat. Physical changes in matter are reversible—matter can go back and forth between one state and another without changing the chemical make-up of the matter. In other words, even if water changes from a solid to a liquid to a gas and then back to a liquid, it is still water. The chemistry of water doesn't change even though it changes states.

Chemical Changes

Physical changes aren't the only ways that matter can change. Suppose you want an egg for breakfast. When you cook the egg, it undergoes a **chemical change.** The raw egg and the cooked egg are chemically different. A chemical change is a change in matter that happens when the arrangement of atoms in molecules is changed and a new substance is formed.

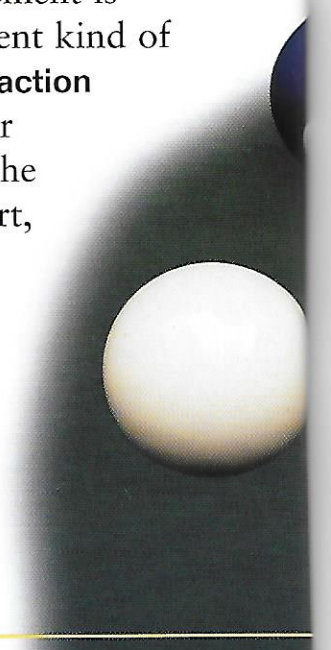
Cooked eggs aren't the only things that undergo a chemical change. Just think about plastic—it's also a result of chemical changes in matter. Plastics belong to a group of materials called polymers. Polymers are made of long chains of molecules strung together. Before the mid-1800s, the only polymers that scientists knew about made up natural substances, such as wood and stone. Later, chemists began experimenting to make artificial polymers. Today plastics are the most widely used type of artificial polymer. From plastic bags to valves in artificial hearts, plastics have changed our world.



When an egg is cooked, it undergoes a chemical change.

The New Alchemists

Over the last century, scientists have discovered that chemical and physical changes aren't the only changes that happen in matter. After many experiments, scientists discovered that some elements could change into other elements. This was the kind of change sought by the alchemists hundreds of years earlier! When one element is changed into a different kind of element, a **nuclear reaction** takes place. A nuclear reaction happens in the nucleus, or center part, of an atom.



Some of the first artificial polymers were used to make billiard balls.

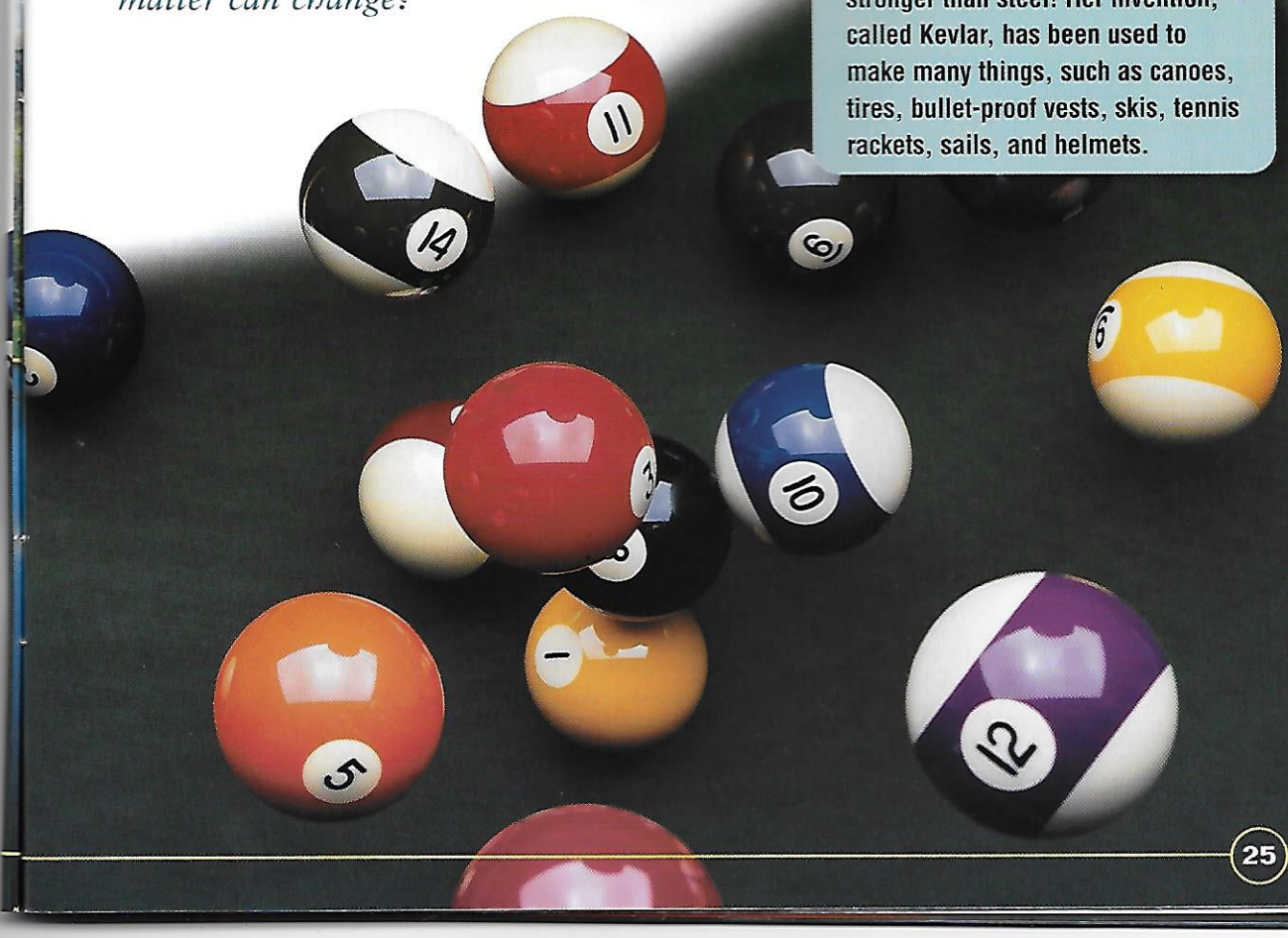
There are two types of nuclear reactions, fission and fusion. In a fission reaction, the nucleus of a large atom breaks apart to form smaller atoms. In a fusion reaction, small atoms join, or fuse, to form larger atoms. By discovering how one element can change into another, scientists are fulfilling one of the alchemists' dreams. They haven't turned lead into gold, but they are unlocking the mysteries of matter.

What are three ways matter can change?

Focus On

Stephanie Kwolek: A Bullet-Proof Inventor

Stephanie Kwolek was born in 1923 in Pennsylvania. She studied chemistry and biology in college and then worked in a polymer lab. One day, she created a substance that was very thin, yet five times stronger than steel! Her invention, called Kevlar, has been used to make many things, such as canoes, tires, bullet-proof vests, skis, tennis rackets, sails, and helmets.



Hands-on Science

Changing Matter

Long before people had electric or gas freezers, they were enjoying the taste of ice cream, even in the hot summer. They made this delicious dessert by changing milk and syrup into a treat. Try the activity to see how you can change matter and make a frozen treat.

Materials

- ✔ Large empty container with lid
- ✔ Small plastic container with lid
- ✔ Ice cubes
- ✔ Measuring cup
- ✔ Milk (125 milliliters or 4 ounces)
- ✔ Flavored syrup (1 spoonful)
- ✔ Salt
- ✔ Spoon
- ✔ Winter gloves

Explore

1. Fill the small container with the milk and syrup. Stir. Write down the properties of this mixture.
2. Seal the small container tightly and place it in the larger container.
3. Fill the rest of the large container with ice and add about 1 cup of salt.

4 Seal the large container and begin shaking. The container will get very cold, so make sure you wear your gloves.

5 After 10 minutes, stop shaking, open the large container, and take out the small container. Open the small container. If the contents are not frozen, put it back into the large container and add some more ice and salt. Seal it back up and shake the container for 5 more minutes.

6 Once the mixture in the smaller container is frozen, write down the properties of the mixture.
Note: Do not eat the frozen treat unless your teacher says it is okay.

Think

In what state of matter were the milk and syrup at the beginning of the experiment? In what state of matter were they at the end? Did a physical change or chemical change take place? How do you know?