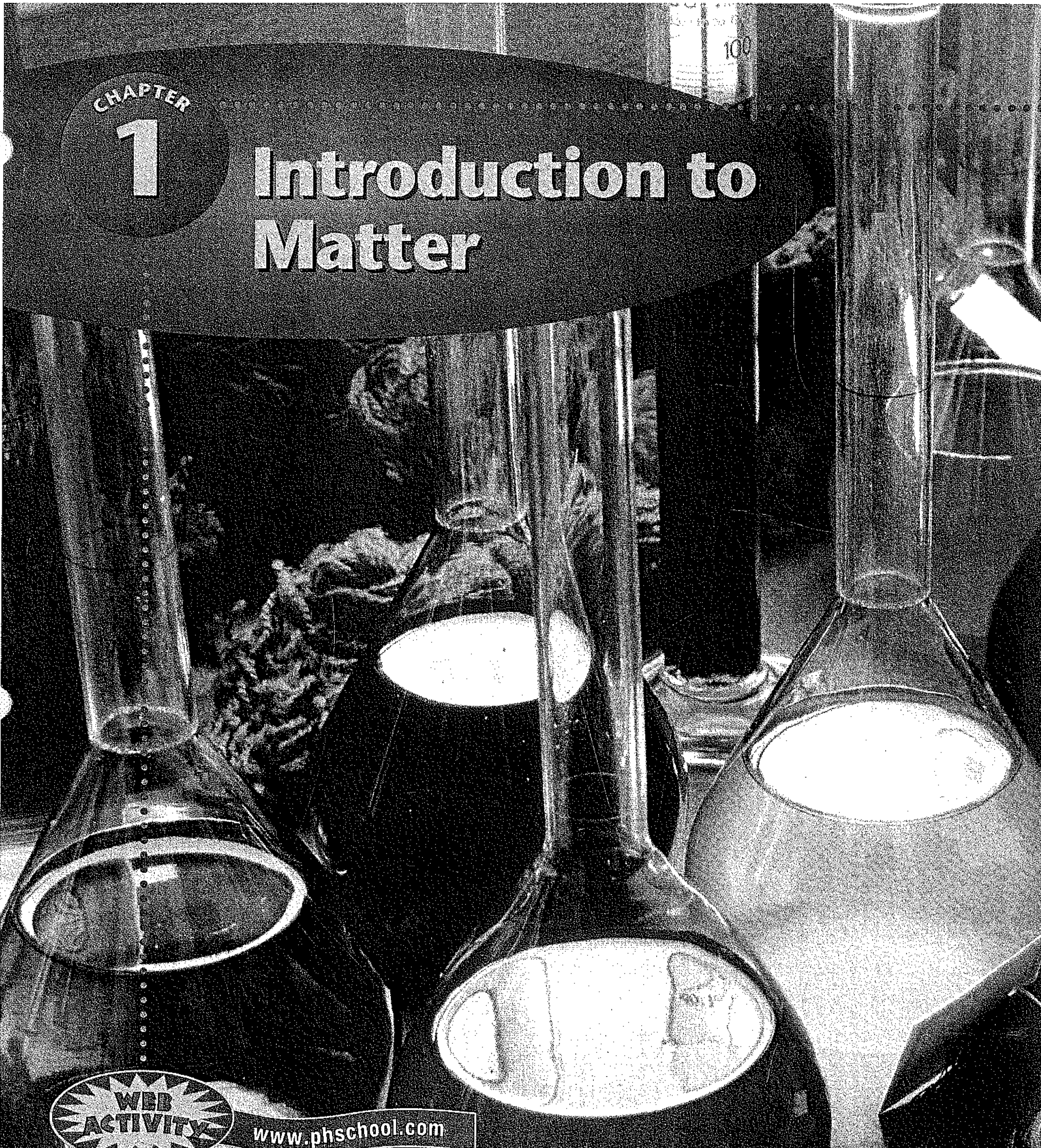
CHAPTER 1

# Introduction to Matter



WEB ACTIVITY www.phschool.com

## SECTION 1 Describing Matter

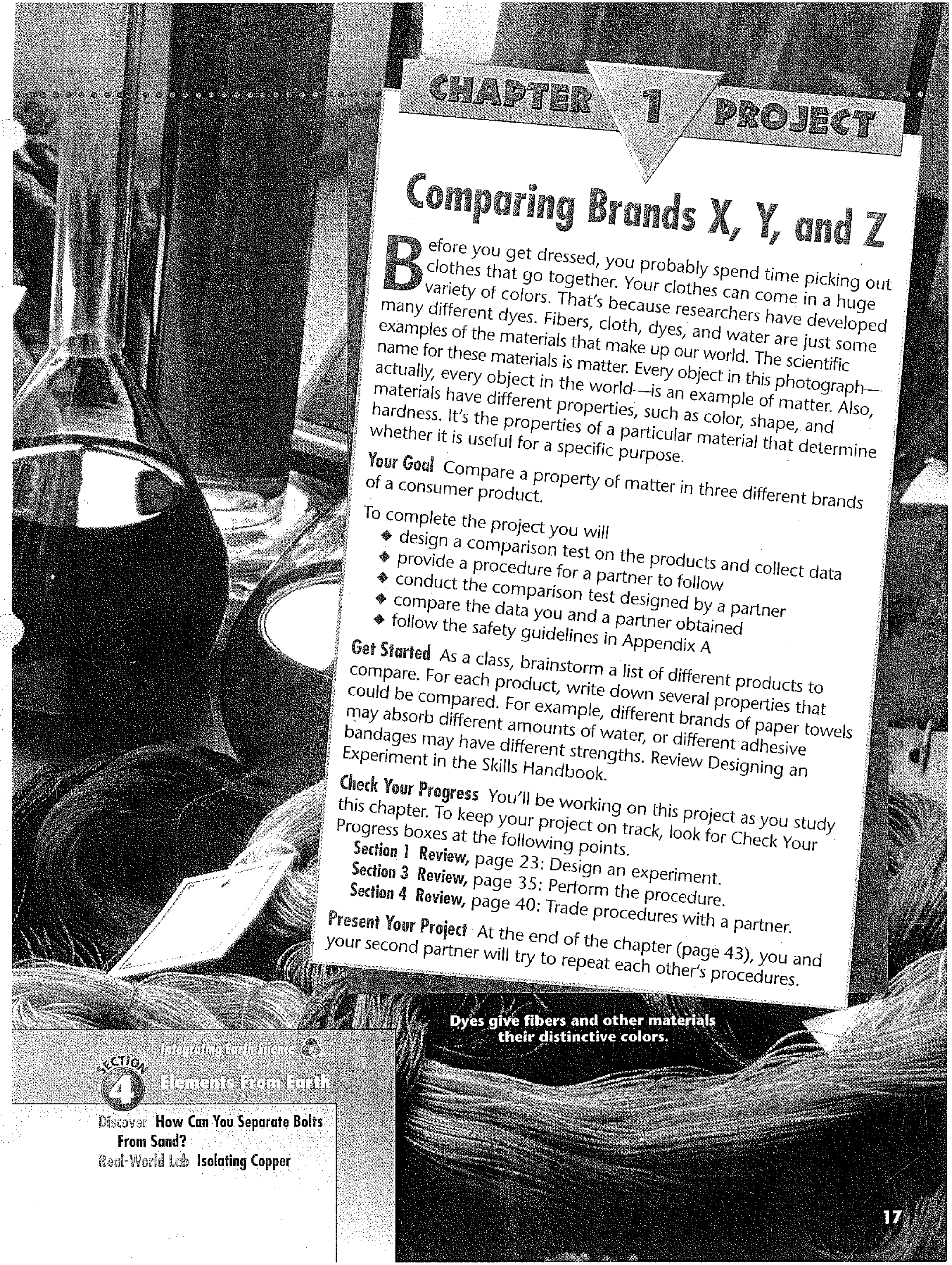
Discover What Properties Help You Sort Matter?
Sharpen Your Skills Inferring

## SECTION 2 Measuring Matter

Discover Which Has More Mass?
Try This Bubble Time
Skills Lab Making Sense of Density
Science at Home Density Demonstration

## SECTION 3 Particles of Matter

Discover What's in the Box?



Dyes give fibers and other materials their distinctive colors.

CHAPTER 1 PROJECT

# Comparing Brands X, Y, and Z

Before you get dressed, you probably spend time picking out clothes that go together. Your clothes can come in a huge variety of colors. That's because researchers have developed many different dyes. Fibers, cloth, dyes, and water are just some examples of the materials that make up our world. The scientific name for these materials is matter. Every object in this photograph—actually, every object in the world—is an example of matter. Also, materials have different properties, such as color, shape, and hardness. It's the properties of a particular material that determine whether it is useful for a specific purpose.

**Your Goal** Compare a property of matter in three different brands of a consumer product.

To complete the project you will

- design a comparison test on the products and collect data
- provide a procedure for a partner to follow
- conduct the comparison test designed by a partner
- compare the data you and a partner obtained
- follow the safety guidelines in Appendix A

**Get Started** As a class, brainstorm a list of different products to compare. For each product, write down several properties that could be compared. For example, different brands of paper towels may absorb different amounts of water, or different adhesive bandages may have different strengths. Review Designing an Experiment in the Skills Handbook.

**Check Your Progress** You'll be working on this project as you study this chapter. To keep your project on track, look for Check Your Progress boxes at the following points.

**Section 1 Review,** page 23: Design an experiment.
**Section 3 Review,** page 35: Perform the procedure.
**Section 4 Review,** page 40: Trade procedures with a partner.

**Present Your Project** At the end of the chapter (page 43), you and your second partner will try to repeat each other's procedures.

Chapter 1 - Physical Science

SECTION 1

# Describing Matter

## DISCOVER ACTIVITY

### *What Properties Help You Sort Matter?*

1. Carefully examine the ten objects that your teacher provides. Write a brief description of each object. What properties are unique to each object? What properties do some objects have in common?
2. Which objects appear to be made of a single substance? Which objects appear to be mixtures of different substances?
3. Divide the objects into small groups so that the objects in each group share one of the properties you identified.

**Think It Over**

***Classifying*** Share your observations and grouping with your classmates. How do the ways your classmates grouped the objects compare with the way you grouped the objects? Think of at least one other way to group the objects.

**GUIDE FOR READING**

- ◆ How can an unknown substance be identified?
- ◆ Why are elements called the building blocks of matter?
- ◆ What are two basic ways that matter can change?

***Reading Tip*** **Before you read, use the headings to outline the section. As you read, add information to your outline.**

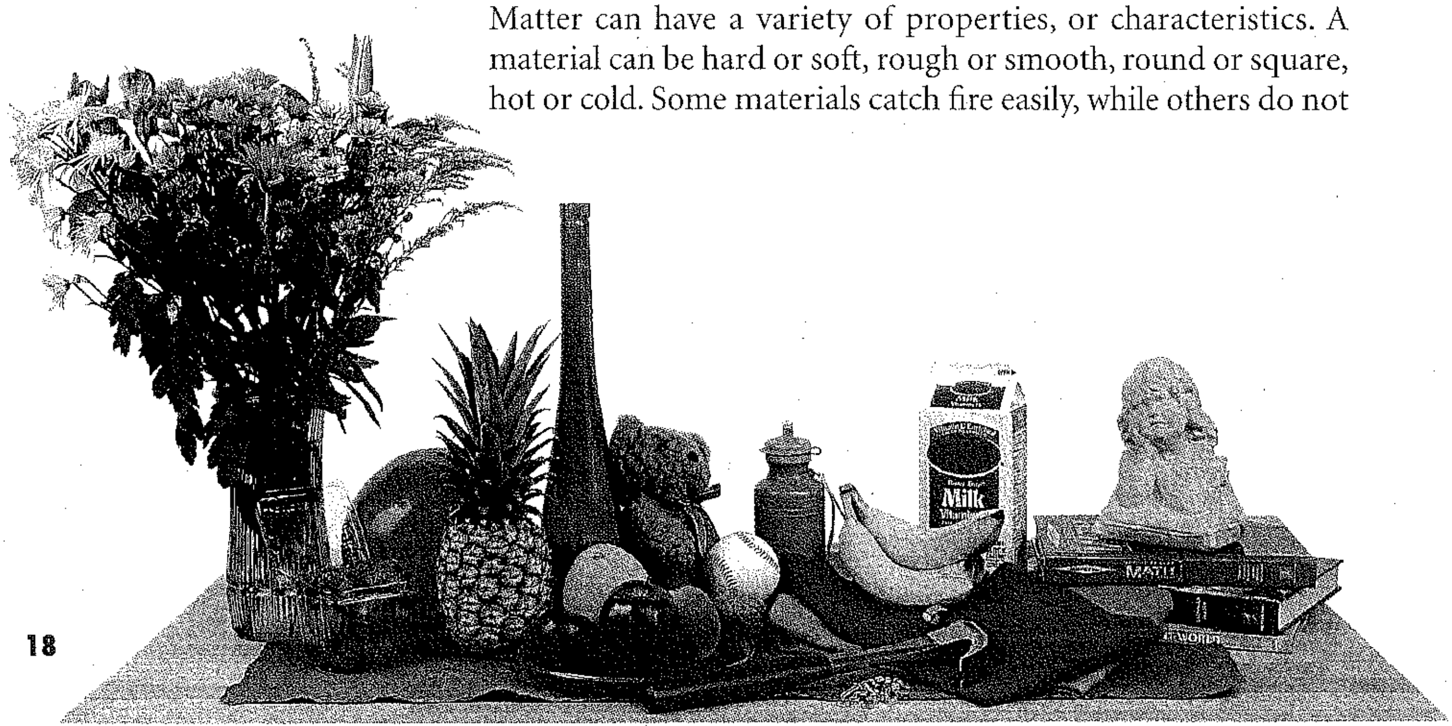
You have probably heard the word *matter* used in lots of ways. "It doesn't matter!" "As a matter of fact, . . ." "Hey, what's the matter?"

In science, however, it has a specific meaning. **Matter** is anything that has mass and takes up space. It is the "stuff" that makes up everything in the universe. Fruit, baseballs, statues, milk, books, flowers: These and every other object are examples of matter. Even air is matter. Air may be invisible, but you know it is there when you feel a cool breeze or watch trees bend in the wind.

What exactly is matter? This question is not so easy to answer! You can begin by looking at some of its properties.

## Properties of Matter

Matter can have a variety of properties, or characteristics. A material can be hard or soft, rough or smooth, round or square, hot or cold. Some materials catch fire easily, while others do not



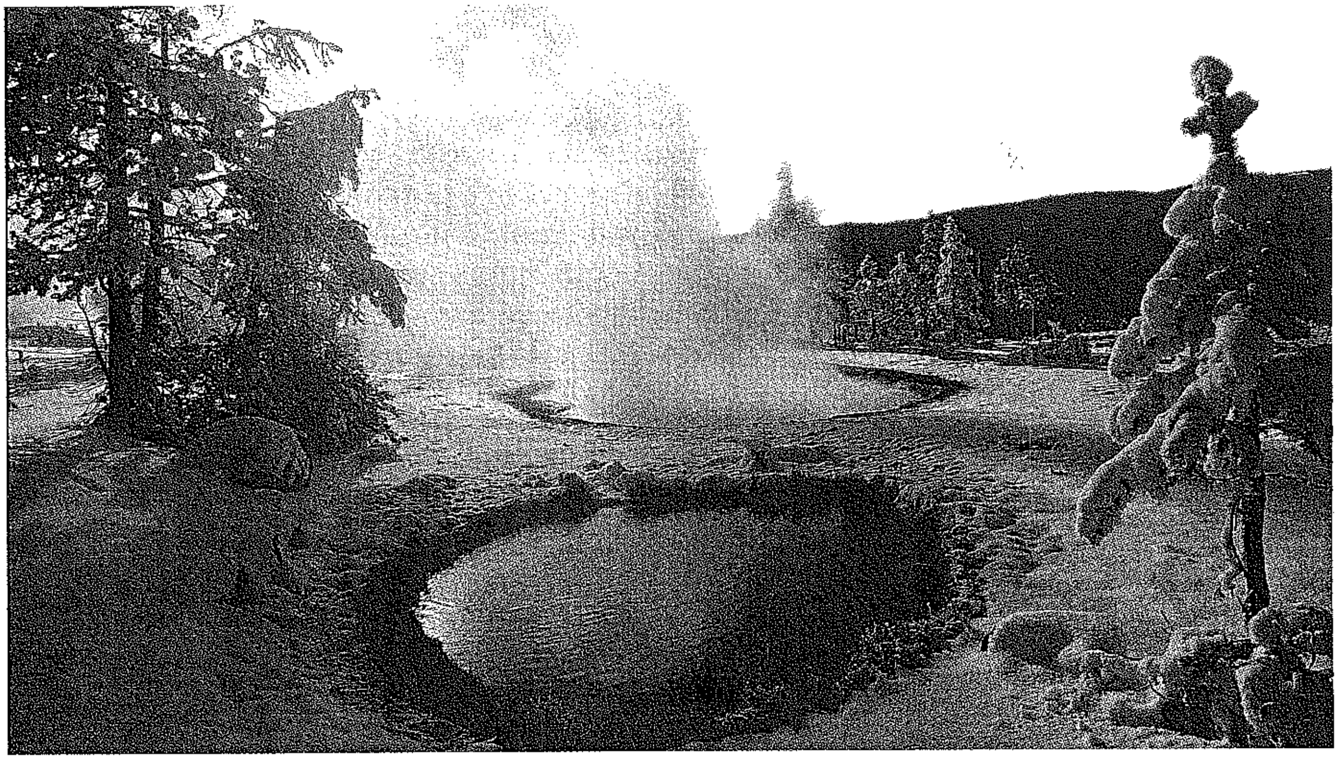


**Figure 1** Surrounded by snow, a geyser gives off hot water and steam—small droplets of hot liquid water in air. It also gives off water vapor, a gas you cannot see. These events display just a few of water's properties. ***Predicting*** *How will the snow change if its temperature increases above 0°C?*

burn. Matter may be any color—or have no color at all. Hardness, texture, shape, temperature, flammability, and color are all examples of properties of matter.

**Each specific substance has its own combination of properties that can be used to identify the substance.** For example, you could tell whether or not a particular substance is water by its properties. Water is a clear, colorless liquid at room temperature. At temperatures of 0°C or lower, water changes into ice. At temperatures of 100°C or higher, water changes into water vapor, an invisible gas. Investigating properties like these is one of the jobs that chemists do. **Chemistry** is the study of the properties of matter and how matter changes.

## Kinds of Matter

Take an imaginary walk through your neighborhood and notice the buildings. It's easy to tell the difference between a gas station, an office building, and a supermarket. Yet they are built of just a few kinds of materials. Bricks, wood, glass, stone, concrete, and steel are among the most common. Using the same materials, people make many different structures.

**Elements** Just as many different buildings are made from just a few kinds of materials, all the different kinds of matter in the universe are made from about 100 different substances, called elements. An **element** is a substance that cannot be broken down into any other substances by chemical or physical means. **Elements are called the building blocks of matter because all matter is composed of elements.** Each element is made up of tiny particles called **atoms.**

## Math TOOLBOX

### Ratios

A ratio compares two numbers. It tells you how much you have of one item in comparison to how much you have of another. For example, a recipe for cookies calls for 2 cups of flour for every 1 cup of sugar. You can write the ratio of flour to sugar as:

2 to 1 or 2 : 1

The elements in a compound are present in a specific ratio. If two compounds contain the same elements in different ratios, such as CO and $CO_2$, they are different compounds.

You are already familiar with some elements, such as aluminum in foil or copper in a penny. Others, such as tungsten, may be new to you. Each element has its own symbol. That **symbol** is a one- or two-letter set of characters used to identify an element. Examples include aluminum (Al), carbon (C), copper (Cu), hydrogen (H), gold (Au), iron (Fe), and oxygen (O).

**Compounds** Elements can exist in an uncombined or a combined form. For example, most of the oxygen present in the air is not combined with another element. In nature, however, most elements are found combined with one or more elements in a compound. A **compound** is a substance made of two or more elements chemically combined in a specific ratio. For example, the carbon dioxide gas ($CO_2$) you give off when you breathe is a compound made of carbon atoms and oxygen atoms in a 1 to 2 ratio (one part carbon to two parts oxygen).

Each compound is represented by a formula that uses symbols to identify which elements are present. A **formula** is a combination of symbols that shows the ratio of elements in a compound. You may know that water has the formula $H_2O$. That tells you that the ratio of hydrogen atoms to oxygen atoms is 2 to 1. If you see a compound with a different formula, such as $H_2O_2$, you know that the compound cannot be water. $H_2O_2$ is hydrogen peroxide, a medicine used to clean cuts and scrapes. $H_2O_2$ and $H_2O$ each has its own set of properties.

☑ *Checkpoint* *How do compounds differ from elements?*

**Mixtures** Most matter that you find in the environment occurs as mixtures. A **mixture** is made from two or more substances—elements, compounds, or both—that are together in the same place but are not chemically combined into a new substance. For example, water is not found in a pure state in nature. Instead, it is found as a mixture that contains dissolved oxygen, salts, and other substances.

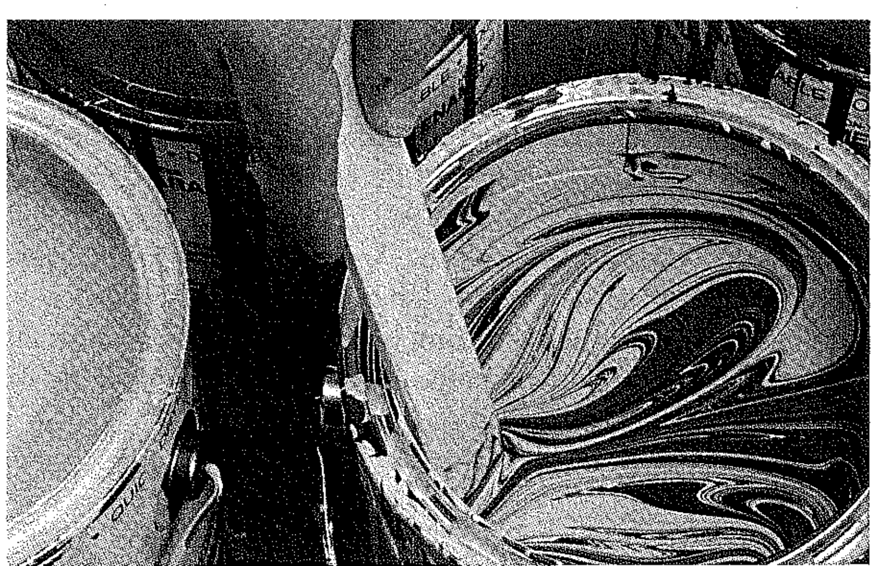


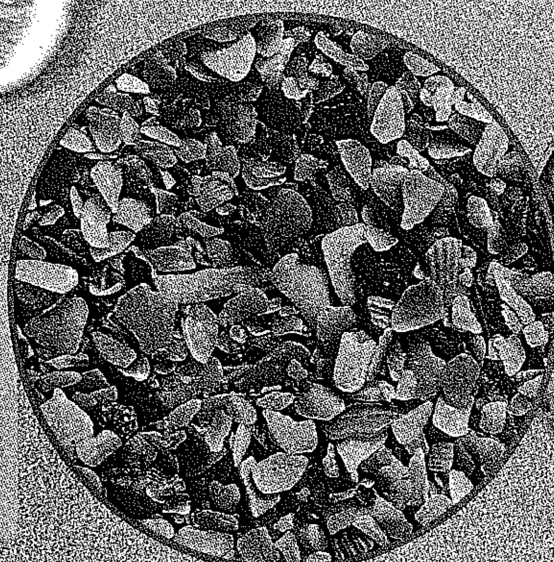
**Figure 2** The element silver (above) is sometimes found in a wiry, treelike form. The paints (right) are mixtures of several compounds. Those compounds that give paints their colors are called pigments.

# EXPLORING *Matter at the Beach*

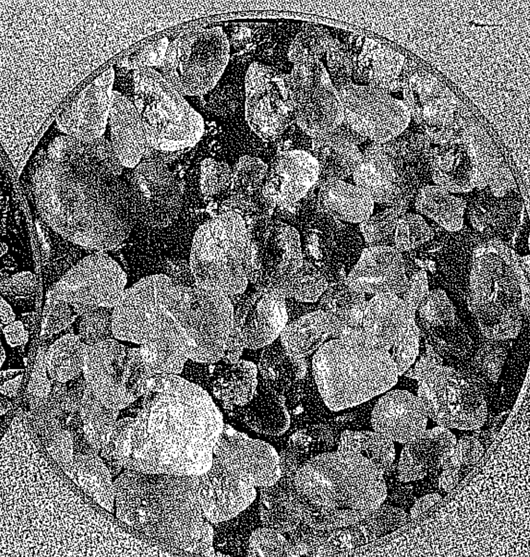
**You can find all sorts of matter at an ocean beach, including sand, seashells, grasses and other plants, and sea water. Many types of beach sand are made up of small rocks and other particles that are washed ashore by the ocean's waves.**

**Mixture**
Some beach sand is a mixture of a substance called quartz and tiny fragments of seashells. The color of beach sand depends on the types of shells it contains.

**Compounds**
Seashells contain different calcium compounds, including calcium carbonate. Quartz is formed from a compound called silicon dioxide.



*Calcium carbonate*

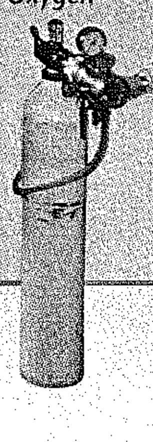


*Silicon dioxide*

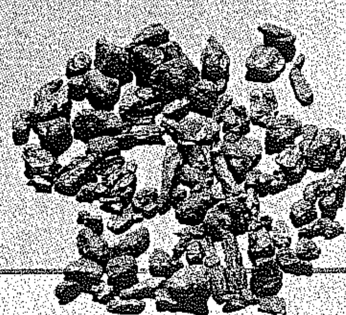
**Elements**
The compounds in beach sand are made mostly of four elements: silicon, oxygen, calcium, and carbon. Like most substances, beach sand shares few properties with the elements that it is made up of.

*Silicon*

*Oxygen*



*Calcium*



*Carbon*

## Sharpen your Skills

### Inferring

ACTIVITY

1. Obtain a mixture of sand and iron filings. Place the mixture in the center of a piece of paper.
2. Examine the mixture carefully. Predict the effect a magnet would have on it.
3. Hold a magnet below the paper under the mixture. Move the magnet toward the edge of the paper.
4. Use the magnet to separate as much of the mixture as you can.
5. Was your prediction in Step 2 correct? What property allowed you to separate parts of the mixture?

Mixtures differ from compounds in two ways. First, the substances in a mixture keep their individual properties. Soil, for example, is a mixture of sand, clay, water, and other materials. If you look closely at soil, you can see the sand particles. Second, the parts of a mixture are not necessarily present in specific ratios. Different soils contain different amounts of sand and clay.

☑ *Checkpoint* *Why is soil a mixture and not a compound?*

## Changes in Matter

Imagine going to a costume party and seeing someone dressed as a clown. Could it be someone you know? How can you tell?

**Physical Change** Putting on a costume can make someone look quite different, but the person hasn't changed. So it is with changes in matter that do not produce a new substance. A change that alters the form or appearance of a material but does not convert the material into new substances is called a **physical change.** Examples of physical changes include chopping wood, bending copper wire into new shapes, and changes in state.

Matter has three principal states—solids, liquids, and gases. A substance, such as water, can change from one state to another when the temperature changes. But water remains the same substance, whether it's in the form of a solid, a liquid, or a gas. It is still made of two parts hydrogen and one part oxygen ($H_2O$).

Investigating changes of state is one way chemists study matter. For example, under ordinary conditions, some substances are solids, while others are liquids or gases. And some of these substances change state with just a small amount of heating or cooling, while others require intense heat or extreme cold. Chemists try to explain those differences.

**Figure 3** When you make a giant soap bubble, you cause a physical change to occur. The bubble is a thin film of liquid that surrounds a body of air.

**Chemical Change** A change in matter that produces new substances is called a **chemical change,** or a **chemical reaction.** The new substances are made of the same elements as the original substances, but the atoms are rearranged in new combinations. In a chemical change, elements may combine to form compounds, or compounds may be broken down into elements, or compounds may change into other compounds. Some familiar examples of chemical changes include the rusting of iron and the burning of gasoline in a car engine.

**Physical changes and chemical changes are the two basic ways that matter can change.** To illustrate the difference between these two changes, think of elements as letters and compounds as words. Just as a word is made of certain letters in a specific combination, a compound is made of certain elements in a specific combination.

A physical change is like printing the same word in a different style of type without changing the word:

**stampedes** → *stampedes*

A chemical change is like rearranging the letters of the original word to make one or more new words:

**stampedes** → **made** + **steps**

The new substances formed during a chemical change always have their own set of properties.

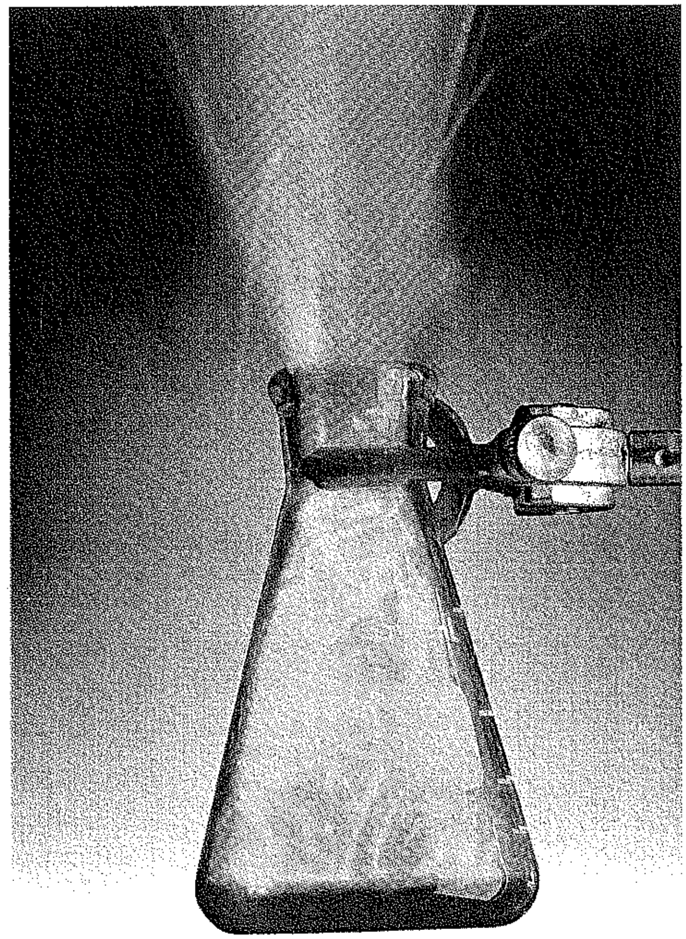


**Figure 4** In this explosive chemical change, the elements sodium (Na) and bromine (Br) combine to form the compound sodium bromide.

## Section 1 Review

1. Name several properties of matter that help you identify an unknown substance.
2. What substances are the building blocks of matter?
3. Explain the difference between a physical change and a chemical change.
4. How does a chemical formula differ from a symbol?
5. **Thinking Critically Applying Concepts** You see a solid that looks like an ice cube, but it does not melt at room temperature. Can the solid be frozen water? Explain.

CHAPTER PROJECT

### Check Your Progress

Choose which product and property you will test. Design a procedure to test your chosen property of a product. Decide which variables you will keep constant. Describe how you will measure and organize the data you will collect. Work with a partner to discuss ideas for your procedure. Answer your partner's questions about the procedure, listen to any comments offered, and incorporate appropriate comments into your plan.

# Section 2 Measuring Matter

## DISCOVER — ACTIVITY

### *Which Has More Mass?*

1. Your teacher will provide you with some small objects, such as a rock, a plastic drinking cup, an aluminum can, and a pencil. Look at the objects, but do not touch them.
2. Predict which object is lightest, which is second lightest, and so on. Record your predictions.

3. Use a triple-beam balance to find the mass of each object.
4. Based on your results, list the objects from lightest to heaviest.

**Think It Over**

***Drawing Conclusions*** How did your predictions compare to your results? Are bigger objects always heavier than smaller objects? Why or why not?

**GUIDE FOR READING**

- What is the difference between weight and mass?
- How is density calculated?

***Reading Tip*** Before you read, define mass, volume, and density in your own words. Then revise your definitions as you read.

Here's a riddle for you: Which weighs more, a pound of feathers or a pound of bricks? If you answered "a pound of bricks," think again. Both weigh exactly the same—one pound!

There are all sorts of ways of measuring matter, and you use these measurements every day. Scientists rely on measurements as well. In fact, scientists work hard to make sure that their measurements are as accurate as possible.

## Mass

A veterinarian wants an updated weight for a dog at its annual checkup. To find the weight, the owner holds the dog and steps on the scale in the vet's office. Their combined body weight presses down on springs inside the scale. The more the owner and the dog weigh, the more the springs compress and the higher the reading. When the owner's weight is subtracted from the total, the vet knows the weight of the dog.

However, a scale would not indicate the same weight if you were on the moon. Step on a scale on the moon, and the springs inside it wouldn't compress as much as they do on Earth. You would weigh less on the moon.

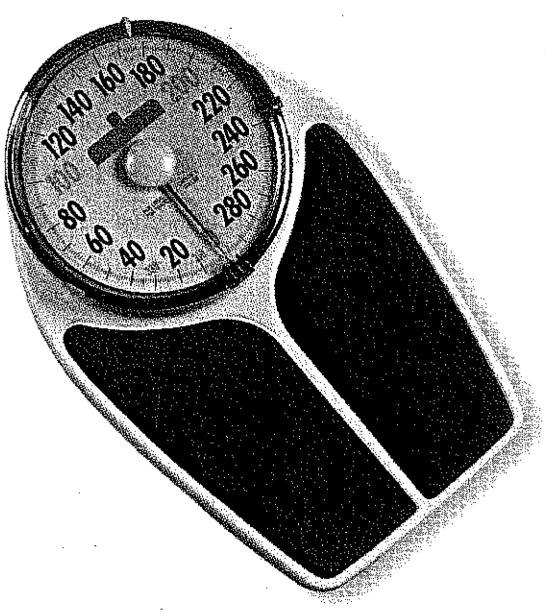



**Figure 5** If you stood on this scale on the moon, it would show that your weight is less there than on Earth.

**Weight and Mass** Your **weight** is a measure of the force of gravity on you. On Earth, all objects are attracted downward by Earth's gravity. On other planets, the force of gravity may be more or less than it is on Earth. On the moon, the force of gravity is much weaker than it is on Earth, which is why you would weigh less on the moon.

In everyday life, weight is a useful measurement of how much matter an object has. But scientists rely on a property that is constant wherever the object may be. This property is called mass. The **mass** of an object is the measurement of how much matter it contains. **Unlike its weight, an object's mass will not change if the force of gravity on it changes.** For this reason, mass is a useful physical property for describing and measuring matter.

**Units of Mass** To measure the properties of matter, scientists use a system of units called the **International System of Units.** The system is abbreviated "SI," after its French name, Système International. For mass, the SI unit is the kilogram (kg). If you weigh 90 pounds on Earth, then your mass is approximately 40 kilograms.

Although you sometimes will see kilograms used in this textbook, usually you will see a smaller unit—the gram (g). There are exactly 1,000 grams in a kilogram. A nickel has a mass of about 5 grams, a baseball has a mass of about 150 grams, and the water in a medium-sized drinking glass has a mass of about 200 grams.

☑ *Checkpoint* *What is the SI unit for mass?*

## Volume

The amount of space that matter occupies is called its **volume.** It's easy to see the volume that solid and liquid objects take up. But gases have volume, too. Watch a balloon as you blow into it. You're actually increasing its volume with your breath.

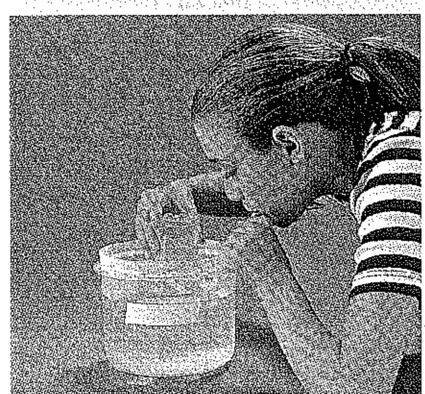
**TRY THIS**

### Bubble Time

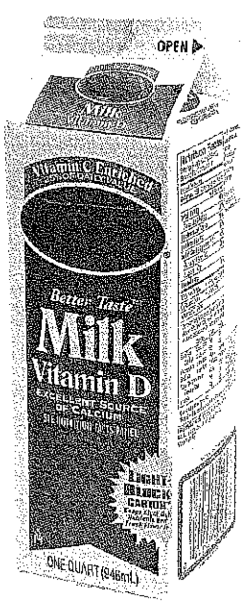
ACTIVITY

Do gases have volume?

1. Fill a large container with water. Completely submerge a clear plastic cup, right-side up, in the container.
2. Mark the water level with a piece of tape on the outside of the container.
3. Turn the cup upside down under water, without letting any air bubbles enter the cup.
4. Insert the short end of the straw into the water and up into the cup. Then blow into the straw.



***Inferring*** Did blowing air into the cup change the water level in the container? Explain your observations.



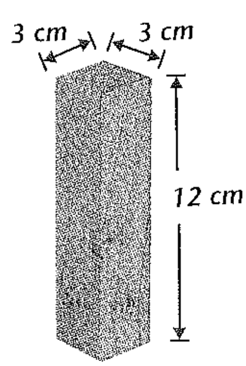




**Figure 6** Volume is measured in several units. Those that scientists commonly use include liters (L), milliliters (mL), and cubic centimeters ($cm^3$).

**INTEGRATING MATHEMATICS** For rectangular objects such as a block of wood, the volume is found by multiplying the measurements of length, width, and height.

$$\textit{Volume} = \textit{Length} \times \textit{Width} \times \textit{Height}$$

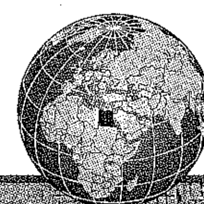
When you multiply the three measurements, you must multiply the units as well as the numbers. So, just as $2 \times 2 \times 2 = 2^3$, $cm \times cm \times cm = cm^3$. If a block of wood has a length of 3 centimeters, a width of 3 centimeters, and a height of 12 centimeters, then the volume would equal the product of those values.

$$\textit{Volume} = 3\ cm \times 3\ cm \times 12\ cm = 108\ cm^3$$

## SCIENCE & History

### Measurement Systems

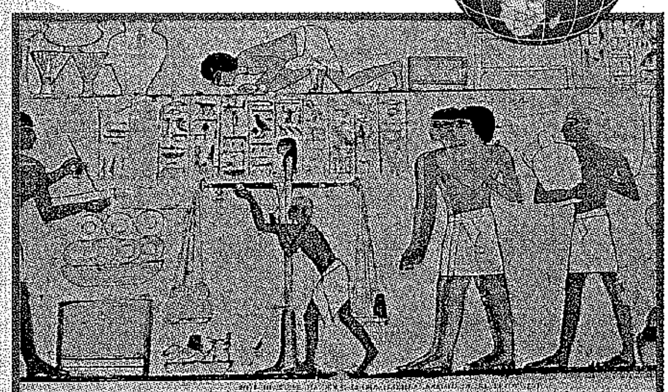
**Like so much else in science, systems of measurement developed gradually over time in different parts of the world.**



**1400 B.C.**

**Egypt**

The ancient Egyptians developed the first known weighing instrument, a simple balance with a pointer. Earlier, they had been the first to standardize a measure of length. The length, called a cubit, was originally defined as the distance between the elbow and the tip of the middle finger.



**1500 B.C. — 1000 B.C. — 500 B.C. — A.D. 1**

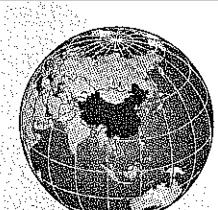
**640 B.C.**

**Lydia**

Merchants in the Middle East and Mediterranean used units of weight to be sure that they received the correct amount of gold and silver in trade and to check the purity of the metal. A *talent* was about 25 kilograms and a *mina* about 500 grams. The Lydians minted the first true coins to have standard weight and value.

**200 B.C.**

**China**



Shih Huang Ti, the first emperor of China, set standards for weight, length, and volume. Even earlier, the Chinese were the first to use decimal notation, the number system based on 10 digits. This is the system most people use today.

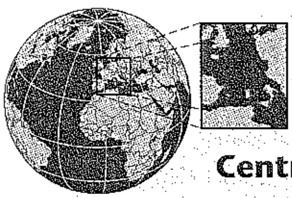
The abbreviation "$cm^3$" is read as *cubic centimeter*, which is a common unit of volume. Other units of volume include the liter (L) and the milliliter (mL), both of which are often used to measure liquids. A milliliter is exactly 1 cubic centimeter. There are 1,000 milliliters in one liter.

How can you measure the volume of an object with an irregular shape, such as a piece of fruit or a rock? One way is to put the object in a graduated cylinder containing water and measure the change in the volume of the water.

☑ ***Checkpoint*** *How can you calculate the volume of a rectangular object such as a shoe box?*

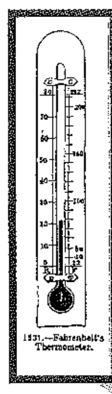
### In Your Journal

Although scientists rely on SI units, people use other measurement units for many different purposes. Research the units used in diamond cutting, horse breeding, sailing, or other activities that interest you. Write a brief essay describing your findings.



**A.D. 789**
**Central Europe**

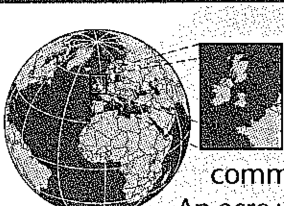
The foot of Charlemagne, emperor of most of central Europe, was set as the standard unit of length. The standard unit of weight was the *Karlspfund,* translated as "Charlemagne's pound."



**A.D. 1714**
**Germany**

Gabriel Fahrenheit invented the thermometer, a temperature-measuring device that relies on the expansion of mercury with heat. His name later came to be used as the name for a temperature scale.

**A.D. 500** | **A.D. 1000** | **A.D. 1500** | **A.D. 2000**



**A.D. 700 England**

During the reign of Ethelbert II in England, the term *acre* was in common use as a measurement of area. An acre was defined as the amount of land that two oxen could plow in one day.

**A.D. 1983**
**France**

The International Bureau of Weights and Measures defines a single set of units that is the same everywhere. Scientists throughout the world use these units in their work.

**Figure 7** This table lists commonly used units of mass, volume, and distance. ***Making Generalizations*** *Which units measure the amount of space an object occupies? Which units measure the amount of matter in an object?*

| Common Units and Conversions | | | |
|---|---|---|---|
| **Quantity** | **SI/Metric Units** | **Other Units** | **Conversions** |
| Mass | Kilogram (kg)<br>Gram (g) | | 1 kilogram = 1,000 grams |
| Volume | Cubic meter ($m^3$)<br>Liter (L)<br>Milliliter (mL)<br>Cubic centimeter ($cm^3$) | Quart<br>Gallon | 1 liter = 1,000 milliliters<br>1 milliliter = 1 $cm^3$ |
| Distance | Meter (m)<br>Kilometer (km)<br>Centimeter (cm) | Foot<br>Mile<br>Inch | 1 kilometer = 1,000 meters<br>1 centimeter = 0.01 meter |

## Density

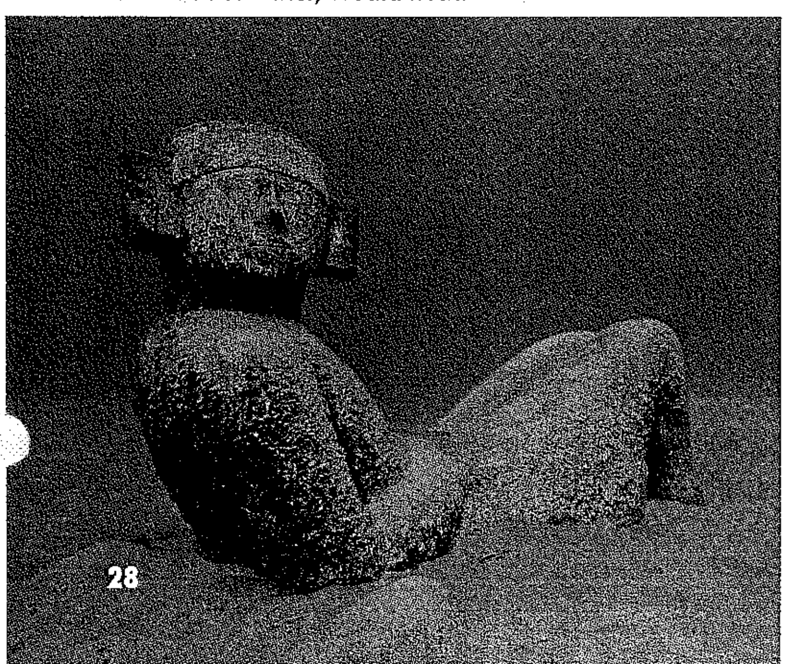
Different substances may have the same mass, but they don't necessarily fill the same volume. Remember the riddle about the bricks and the feathers? A kilogram of bricks takes up a much smaller volume than the same mass of feathers. This is because bricks and feathers have different densities—a very important property of matter. **Density** is the measurement of how much mass is contained in a given volume. **To calculate the density of an object, divide its mass by its volume.**

$$Density = \frac{Mass}{Volume}$$

A unit of density is always a unit of mass, such as grams, divided by a unit of volume, such as cubic centimeters. One typical unit of density is written as "g/$cm^3$," which is read as "grams per cubic centimeter." The word *per* means "for each," which in mathematics is the same as "divided by." For liquids, density is often stated in grams per milliliter, or g/mL. The density of water is 1.0 g/mL, which is the same as 1.0 g/$cm^3$.

Sometimes you can compare the densities of substances just by observing them. For example, suppose you have a solid block of wood and a solid block of gold. When you drop each block into a tub of water, the wood floats and the gold sinks. You know the density of water is 1.0 g/$cm^3$. You can conclude that the wood has a density lower than 1.0 g/$cm^3$. In contrast, the density of the gold is greater than 1.0 g/$cm^3$. In the same way, you can conclude that the density of the solid stone statue in Figure 8 is greater than the density of the water around it.

**Figure 8** An object sinks or floats in water depending, in part, on its density. This stone statue remains on the sea floor where it was placed. A statue of solid wood, with a density less than that of water, would float.



## Sample Problem

A small block of wood floats on water. It has a volume of 25 cubic centimeters and a mass of 20 grams. What is the density of the wood?

*Analyze.* You know the mass and the volume. You want to find the density.

*Write the formula.*

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

*Substitute and solve.*

$$\text{Density} = \frac{20\ g}{25\ cm^3}$$

$$\text{Density} = 0.8\ g/cm^3$$

*Think about it.* The answer shows mass per unit volume. The correct unit is $g/cm^3$.

**Practice Problems**

1. A sample of liquid has a mass of 24 grams and a volume of 16 milliliters. What is the density of the liquid?
2. A metal sample has a mass of 43.5 grams and a volume of 15 cubic centimeters. What is its density?

Watch a bottle of oil-and-vinegar salad dressing after it has been shaken. You will see oil droplets rise toward the top of the bottle. Eventually, the oil forms a separate layer above the other ingredients. What can you conclude? You're right if you said the oil is less dense than the rest of the liquid dressing.

Density is a physical property of a substance. Therefore, density can be used to help identify a substance. For example, all samples of pure gold at a certain temperature have a density of 19.3 $g/cm^3$. Measuring the density of a shiny yellow material is one way to test whether or not that material is gold.

## Section 2 Review

1. How are mass and weight different measurements?
2. What two quantities do you need to know in order to calculate density?
3. Describe how you could measure the volume of an object with an irregular shape.
4. **Thinking Critically Problem Solving** The density of aluminum is 2.7 $g/cm^3$. A metal sample has a mass of 52.0 grams and a volume of 17.1 cubic centimeters. Could the sample be aluminum? Explain your answer.

### Science at Home

**Density Demonstration** Label two cups A and B and place a cup of water in each. Stir 3 small spoonfuls of salt and several drops of food coloring into Cup B. Dip a clear straw into Cup A to a depth of about 2 cm. Place your finger on the end of the straw and transfer it into Cup B to a depth of about 4 cm. Remove your finger from the straw and then replace it. Remove the straw from the cup. Explain to your family what density has to do with the results.

Interpreting Data

Skills Lab

# MAKING SENSE OF DENSITY

If you break an object in half, does its density change? In this lab you will compare the densities of objects of different sizes.

## Problem

Is density a characteristic property of a substance?

## Materials

balance
water
paper towels
wooden stick, approximately 6 cm long
ball of modeling clay, approximately 5 cm wide
crayon with paper covering removed
graduated cylinder, 100 mL

## Procedure

1. Use a balance to find the mass of the wooden stick. Record the mass in a data table like the one at the right.
2. Add enough water to a graduated cylinder so that the stick can be completely submerged. Measure the initial volume of the water.
3. Place the stick in the graduated cylinder. Measure the new volume of the water.
4. The volume of the stick is the difference between the water levels in Steps 2 and 3. Calculate this volume and record it.
5. The density of the stick equals its mass divided by its volume. Calculate and record its density.
6. Thoroughly dry the stick with a paper towel. Then carefully break the stick into two pieces. Repeat Steps 1 through 5 to calculate the density of each of the two pieces.
7. Repeat Steps 1 through 6 using the clay rolled into a rope.
8. Repeat again using the crayon.

## Analyze and Conclude

1. For each of the three objects you tested, compare the density of the whole object with the densities of the pieces of the object.
2. Use your results to explain how density can be used to identify a substance.
3. Why did you dry the objects in Step 6?
4. **Think About It** Predict the results of this experiment if you had used a pencil with an eraser on one end instead of a wooden stick. Explain your prediction.

## More to Explore

Wrap the modeling clay around the wooden stick and predict the density of the object you created. Then measure mass and volume and calculate the density to see if your prediction was correct.

DATA TABLE

| Object | Mass (g) | Volume Change ($cm^3$) | Density ($g/cm^3$) |
|---|---|---|---|
| Wooden Stick | | | |
| Whole | | | |
| Piece 1 | | | |
| Piece 2 | | | |
| Modeling Clay | | | |
| Whole | | | |
| Piece 1 | | | |
| Piece 2 | | | |
| Crayon | | | |
| Whole | | | |
| Piece 1 | | | |
| Piece 2 | | | |

# Section 3 Particles of Matter

## Discover — Activity

### What's in the Box?

1. Your teacher will give you a sealed box that contains one or more objects. Without opening the box, try to find out as much as you can about its contents. Try tilting, turning, shaking, or tapping the box.
2. Ask yourself questions such as these: Are the objects inside round or flat? Do they slide or roll? How many objects are there?
3. Make a list of your observations about the objects in the box.
4. Trade boxes with another group of students and repeat the activity.

**Think It Over**

***Inferring*** Try to imagine what familiar objects would fit your observations. Make a sketch showing what you think the contents look like. How is it possible to make an inference from indirect evidence?

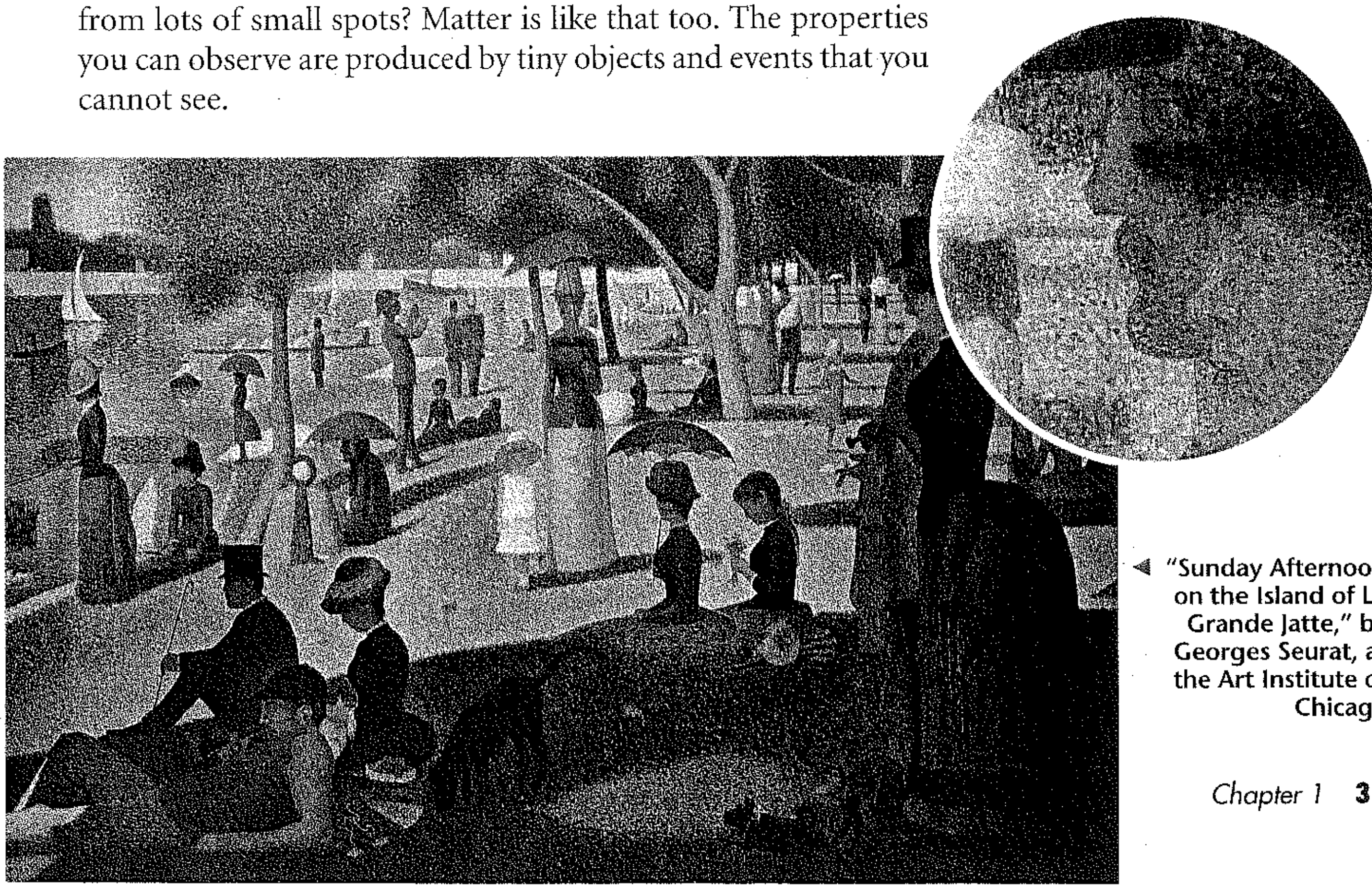
**GUIDE FOR READING**

- **What are the smallest particles of an element?**
- **What did Dalton conclude about atoms?**

***Reading Tip*** **As you read, take notes on the main points under each heading.**

Glance at the painting below and you see people enjoying an afternoon in the park. Look again and notice that some people are in the sunlight and others are in the shade. How did the artist make your eyes see bright light, dark shadows, and shades in between? You can find the answer by looking closely at the circled detail of the painting. The artist used thousands of small spots of color.

Are you surprised that such a rich painting can be created from lots of small spots? Matter is like that too. The properties you can observe are produced by tiny objects and events that you cannot see.



◄ "Sunday Afternoon on the Island of La Grande Jatte," by Georges Seurat, at the Art Institute of Chicago

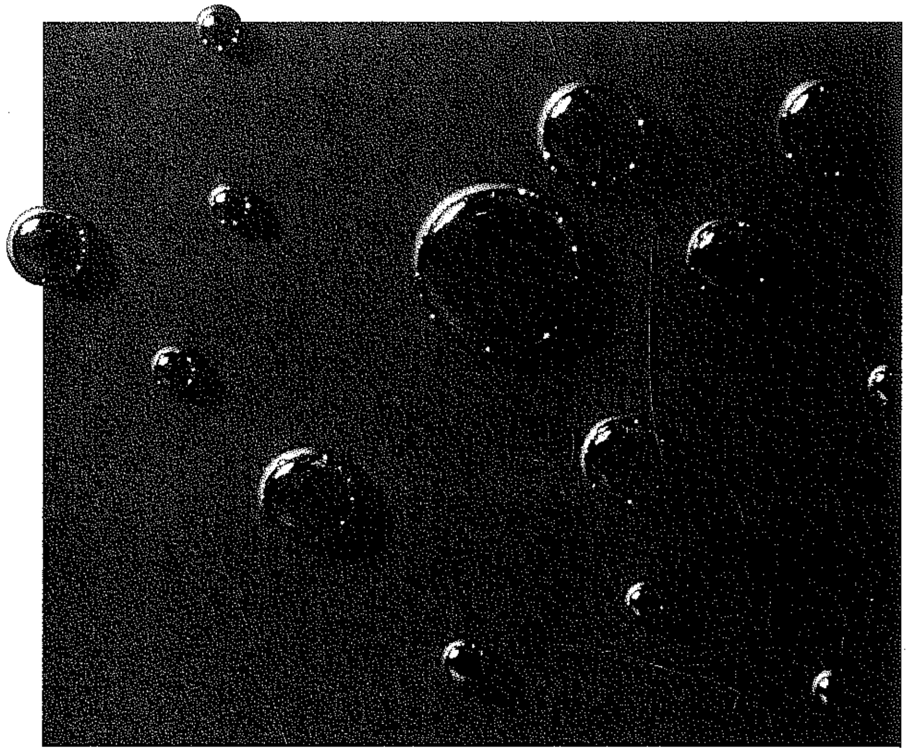


**Figure 9** A drop of spilled mercury breaks into droplets. (Don't do this at home. The element mercury is poisonous and can cause brain damage.) Although these droplets, are small, they are not the smallest particles of mercury possible. ***Applying Concepts*** *What is the smallest particle of an element?*

## Math TOOLBOX

### Scientific Notation

Scientific notation is a way of writing a very large or a very small number as the product of a number between 1 and 10 and a power of 10. The small number written above the 10 is a called an exponent. For example, if you wanted to tell someone that there were 3,000,000,000,000,000,000 atoms in the smallest drop of mercury, you would write $3 \times 10^{18}$ atoms. The exponent tells you that the decimal point is really 18 places to the *right* of the 3. A small number such as 0.000001 mm can be written as $1 \times 10^{-6}$. The negative exponent (−6) tells you that the 1 is in the sixth decimal place.

## Early Ideas About Atoms

What's the smallest possible piece of an element? Think of tearing a sheet of aluminum foil in half, and then tearing the halves into quarters, and the quarters into eighths. Could you keep tearing forever, producing smaller and smaller pieces? Or would you eventually reach the smallest possible piece of aluminum? And if matter is made of such tiny pieces, what are those pieces like? How can they explain the properties of matter that you observe? Philosophers and scientists have asked these kind of questions for more than 2,000 years.

One of the first people known to have thought that matter is formed of small pieces was Democritus, a Greek philosopher who lived about 440 B.C. He thought that you could cut matter into ever smaller pieces until you got to its smallest piece, which couldn't be divided any further. Democritus called this smallest piece *atomos*, which is Greek for "uncuttable." Does that word look familiar? Of course! It's where the word *atom* comes from. **Today scientists use the word *atom* for the smallest particle of an element.**

## Dalton's Ideas About Atoms

A major step in understanding atoms occurred in 1802 when a British school teacher, John Dalton, proposed an atomic theory. No one knows how much Dalton was influenced by the ideas of Democritus. Unlike Democritus and the ancient Greeks, Dalton tested his ideas by carrying out experiments.

Based on the evidence that Dalton found, he inferred that atoms had certain characteristics. Here are his main conclusions.

- *Atoms can't be broken into smaller pieces.* **Dalton imagined atoms to be like tiny marbles, or rigid spheres that are impossible to break.**
- *In any element, all the atoms are exactly alike.* This idea explains why an element always has the same properties.
- *Atoms of different elements are different.* This idea explains why different elements have their own set of properties.
- *Atoms of two or more elements can combine to form compounds.* Compounds can be broken down into elements, so Dalton concluded that compounds had to be made of atoms as well.
- *Atoms of each element have a unique mass.* Dalton and other scientists of his day were not actually able to measure the mass of individual atoms, however.
- *The masses of the elements in a compound are always in a constant ratio.* Water is a compound composed of hydrogen atoms and oxygen atoms. In any two samples of water that have nothing else mixed in with them, the ratio of the mass of hydrogen to the mass of oxygen is always the same.

Today, scientists have identified some important exceptions to Dalton's statements. Even so, Dalton's ideas form the basis of our understanding of atoms.

☑ ***Checkpoint*** *What were two of Dalton's ideas about atoms?*

## Math Toolbox

### Constant Ratios

When two pairs of numbers produce the same ratio, the ratio is said to be constant. Suppose you wanted to increase a recipe that called for 2 cups of flour and 1 cup of sugar. To double the recipe, you would need 4 cups of flour and 2 cups of sugar. The ratio 4 : 2 reduces to 2 : 1 by dividing each number by 2.

$$\frac{4}{2} = \frac{2}{1}$$

To triple the recipe you would need 6 cups of flour and 3 cups of sugar. The ratio 6 : 3 reduces to 2 : 1 by dividing each number by 3.

$$\frac{6}{3} = \frac{2}{1}$$

The two ratios are constant because they both reduce to 2 : 1.

Similarly, for any quantity of a compound, the ratio of the masses of the elements in the compound is constant.

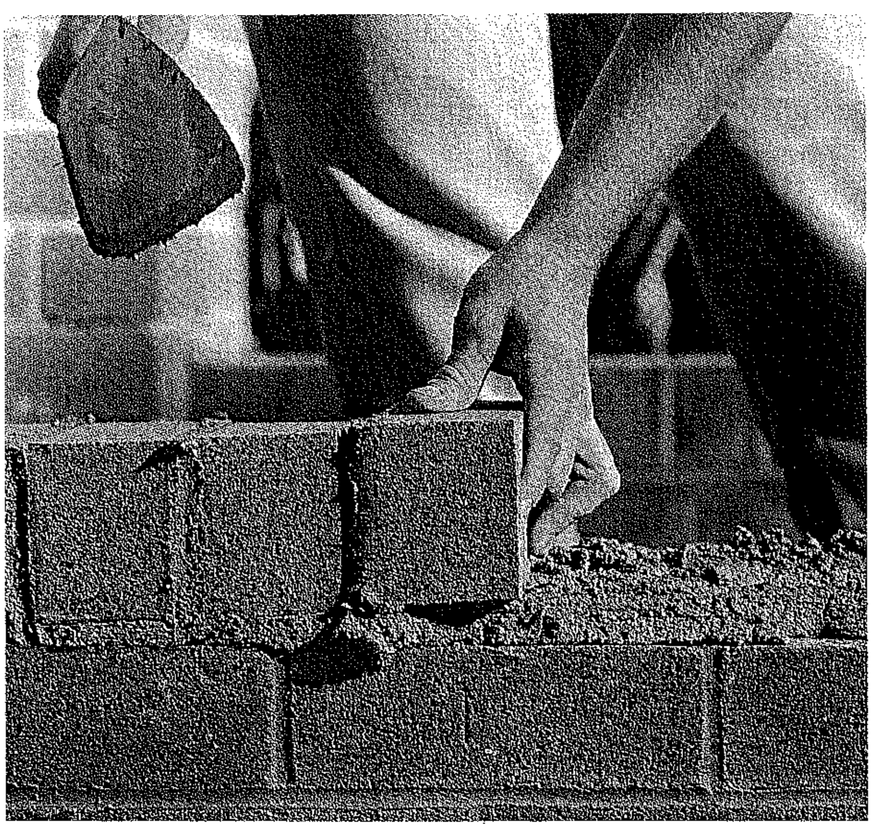


**Figure 10** The compound calcium oxide is part of mortar, the "glue" that holds bricks together. In this compound the ratio of the mass of calcium to the mass of oxygen is always 5 to 2.

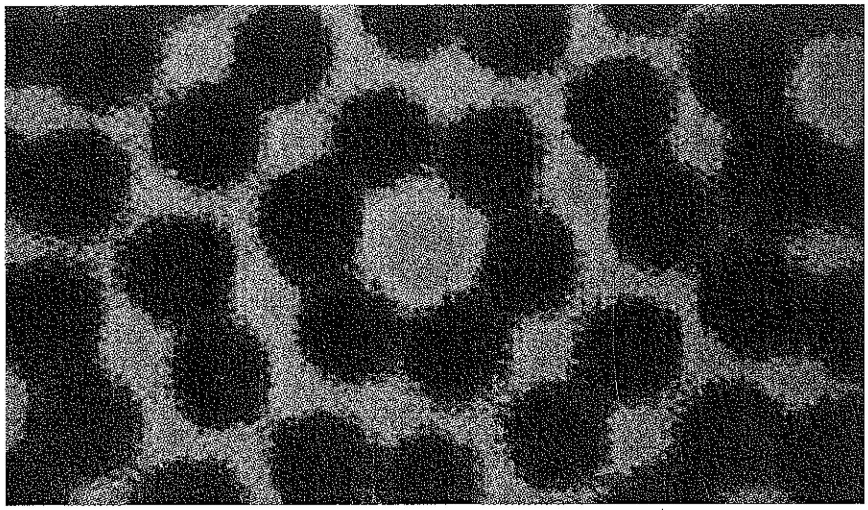


**Figure 11** Here you can see something scientists once thought no one would ever see—atoms! This image of silicon atoms was produced by a scanning tunneling microscope.

## Ideas About Atoms Today

Atoms are so small that for many years no one expected to see them. Just how small? Compare the size of atoms to some everyday objects.

One grain of sand on a typical beach contains more atoms than there are grains of sand on the entire beach.

There are 2,000,000,000,000,000,000,000 (that's 2,000 billion billion) atoms of oxygen in one drop of water—and twice as many atoms of hydrogen!

Newspaper pictures are made from tiny dots of ink. Each dot contains about a billion billion atoms! (That's a 1 followed by 18 zeros!)

Despite their tiny size, there is now a tool that gives a glimpse of what atoms look like. A scanning tunneling microscope can magnify matter so much that it can actually capture images of atoms. Figure 11 shows an example of what this microscope can reveal.

## Atoms and Molecules

An atom can frequently be linked with one or more other atoms. The force that holds two atoms together is a **chemical bond.** A combination of two or more atoms that are bonded together is called a **molecule.** Some molecules are made of atoms that are alike, as in the oxygen gas ($O_2$) that you breathe. Most molecules, though, are made of more than one type of atom. Water molecules have 2 hydrogen atoms combined with 1 oxygen atom ($H_2O$). Acetic acid, the compound that gives vinegar its sharp odor and sour taste, has 2 carbon atoms, 4 hydrogen atoms and 2 oxygen atoms ($C_2H_4O_2$). Molecules can be huge. Some molecules in your body contain millions of atoms.

### Language Arts CONNECTION

In Isaac Asimov's science fiction story *Fantastic Voyage,* people are shrunk down to the size of a single cell. Their experiences inside the body of a full-sized person are "fantastic" reading. Imagine what it would be like to shrink down to the size of a single atom!

*In Your Journal*

Write a one-page story about what you would see and experience as you shrink down to the size of an atom. Explore your new world, describing the other atoms and molecules around you. What happens as you grow back to normal size?

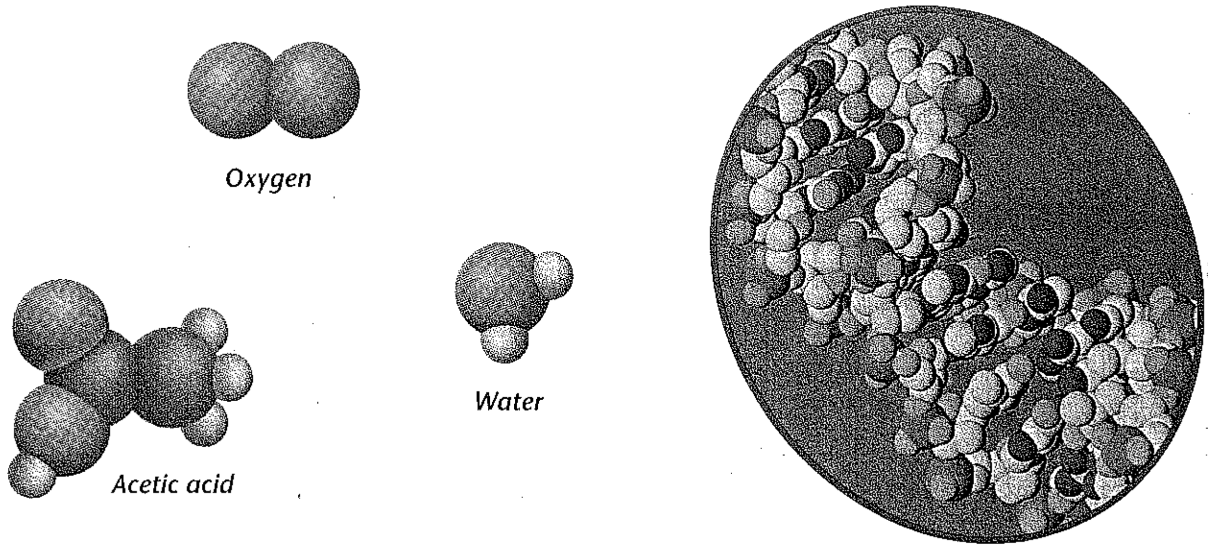



**Figure 12** Each sphere is a model of an atom. The molecule on the right shows a small part of the DNA in living cells. (This computer image of DNA was made using a color code for atoms different from the code used in this book.) *Classifying Which one of these models shows an element? How do you know?*

## The Atom as a Model

Look at the atoms in Figure 11 again. From that image, you cannot really see what atoms look like or discover how they might work. Like a person trying to imagine what's in a box by shaking it, scientists studying atoms must make inferences about them based on observations.

Thus atoms are actually models, mental pictures that explain how matter works. In Chapter 3, you will investigate the atomic model in detail. You will see how it explains the properties of matter and events that you observe every day.

## Section 3 Review

1. What would you get if you could break an element into its smallest particles?
2. What did Dalton visualize atoms to be like?
3. An ice cube consists of molecules of water ($H_2O$). Could you continue, forever, to break an ice cube into smaller and smaller pieces of ice? Explain your answer.
4. **Thinking Critically Interpreting Diagrams** Examine the model of acetic acid ($C_2H_4O_2$) in Figure 12. Which elements are represented by each of the three colors? How do you know? What does the model tell you about the way the different atoms are arranged?
5. **Thinking Critically Calculating** A sample of a compound contains 64 grams of copper and 16 grams of oxygen. What is the ratio of the mass of copper to the mass of oxygen? If another sample of the same compound has 40 grams of copper, how much oxygen is there in the second sample?

CHAPTER PROJECT

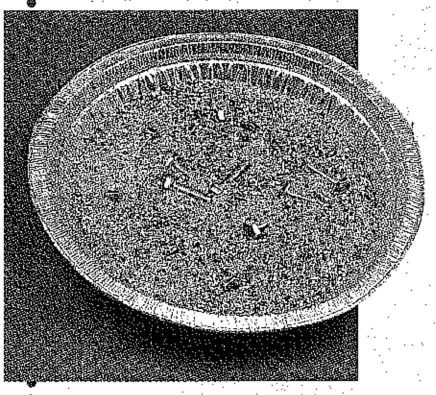
### Check Your Progress

Have your teacher approve your procedure for testing your product. Then obtain the materials you need and perform the test. If you alter the procedure, change the instructions to reflect your alterations. (*Hint:* A good experimental procedure should be reliable. Test more than one sample of the same product to see if your results can be repeated.)

# SECTION 4 Elements From Earth

## DISCOVER ACTIVITY

### How Can You Separate Bolts From Sand?



1. Mix dry sand with a few small metal bolts. Place the mixture in a tray or pie pan.
2. Think of a way to separate the sand and the bolts. You may not use a magnet, but may use water, a bowl, paper towels, and other supplies available in your classroom.
3. With your teacher's permission, try your procedure.

**Think It Over**

***Designing an Experiment*** What properties of matter did you use to separate the sand and the bolts? How successful was your procedure?

**GUIDE FOR READING**

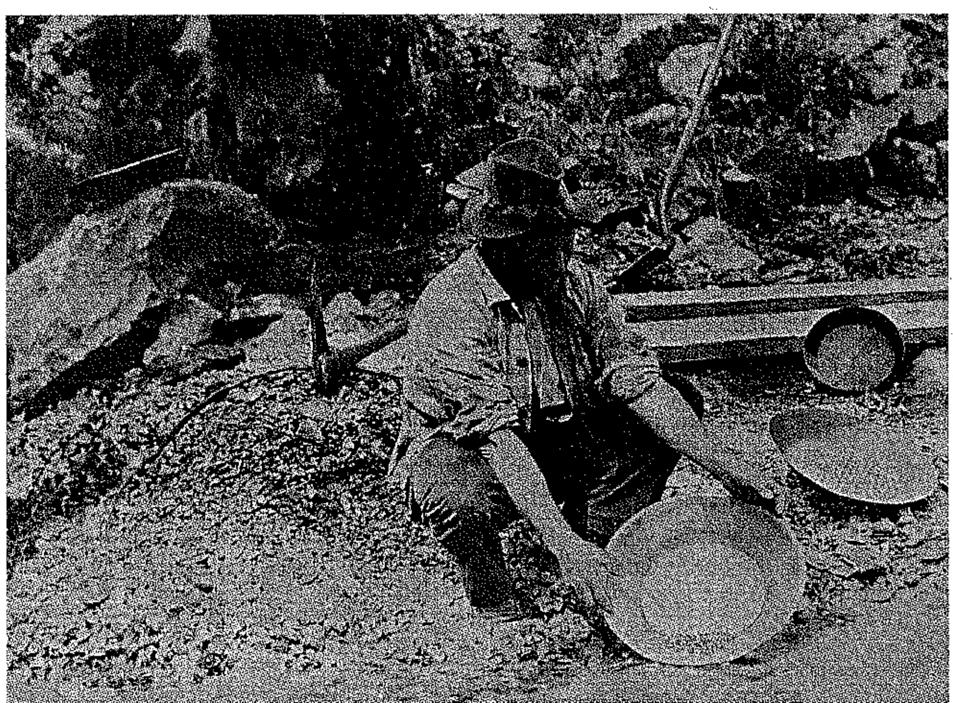
- What property of gold allows it to be panned?
- What must be done to obtain an element from one of its compounds?

***Reading Tip*** As you read, list the ways that people obtain elements from the forms in which they are found in nature.

Gold! In 1848, several gold nuggets were found in the American River in northern California near a mill owned by John Sutter. Thousands of people rushed to California with pans, pickaxes, and shovels. They searched the riverbanks and stream beds hoping to find more nuggets or even gold flakes.

Some people got rich, but many went home empty-handed. Perhaps the most disappointed of all were those who found pyrite, a substance that looks like gold. Pyrite is actually a compound of iron and sulfur. Can you tell why pyrite is also called "fool's gold"?

A gold miner pans for gold in Northern California. ▶



## Gold and Density

**Figure 13** Gold nuggets contain the element gold.

During the California gold rush, miners needed a way to remove the precious metal from a mixture that also contained dirt and sand. **Gold can be separated from other materials in a mixture because of its density.** As you saw in Section 2, gold has a density of 19.3 $g/cm^3$. This is much higher than the density of most other materials, including fool's gold, which has a density of only 5.0 $g/cm^3$.

The miners used a technique called panning. They put the mixture of gold, dirt, and sand into a shallow pan and covered it with water. They then swirled the contents around and carefully poured off the water. The water carried the less dense dirt and sand with it. The more dense gold sank and was left behind. The miners repeated this process until only gold remained in the pan.

Today, gold mining is done on a much larger scale using machines called dredges. But the basic process of separating gold by its density is the same. The dredge scrapes up large amounts of dirt and sand, washes the mixture, and separates the gold in a way that's similar to panning.

☑ *Checkpoint* *What could you do to tell the difference between real gold and fool's gold?*

## Copper and Electrolysis

In nature, finding an element that's not part of a compound is unusual. Most elements, including those people use for industrial purposes in great amounts, are usually found as compounds. For example, copper compounds are most often found in certain kind of ore. An ore is any rock that contains a metal or other economically useful material.

The process of obtaining copper from one of its compounds is more complicated than panning for gold. **To obtain an element from its compound, it is necessary to cause a chemical reaction to take place.** In that chemical change, the copper atoms must be separated from the other atoms in the compound.

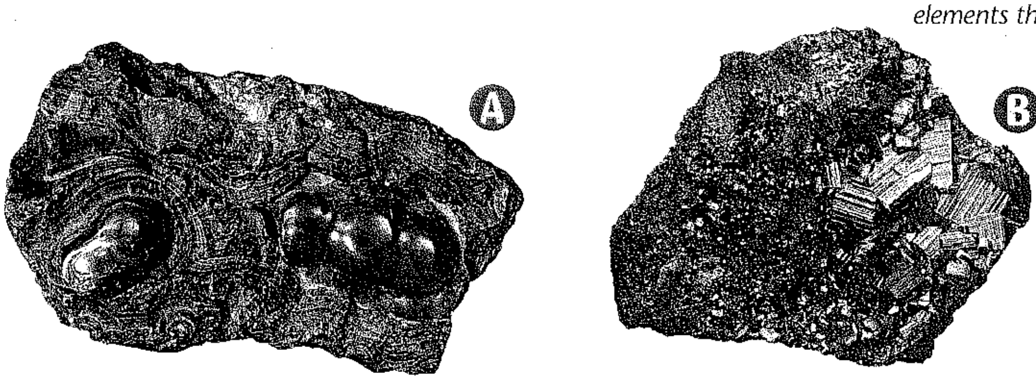



**Figure 14** Ores contain useful elements that are combined with other substances. **A.** Malachite contains copper. **B.** Iron pyrite contains iron.
***Applying Concepts*** *Why do ores have different properties from the elements that they contain?*

Many steps are involved in obtaining copper from its ores. The last step in the process is called **electrolysis.** This term literally means "electric cutting." In one kind of electrolysis, a copper compound is dissolved in water, forming a mixture called a solution. Two metal strips called **electrodes** are placed in the copper compound solution, not touching each other. Each electrode is attached to a wire, and the wires are connected to a source of electric current, such as a battery.

Real-World Lab

How It Works

# Isolating Copper

In nature, copper is usually found in compounds with other elements. In this investigation, you will perform an electrolysis procedure to isolate copper from a compound called copper chloride.

## Problem

How can copper be isolated from a compound by electrolysis?

## Skills Focus

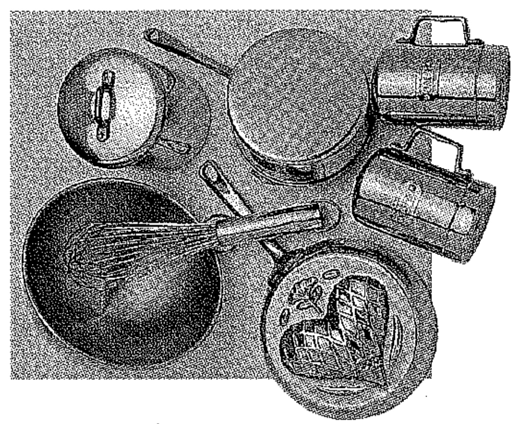
observing, inferring

## Materials

glass jar, about 250 mL
6-volt battery
two paper clips
index card
wires with alligator clips or battery holder with wires
copper chloride solution (0.6 *M*), 50–100 mL

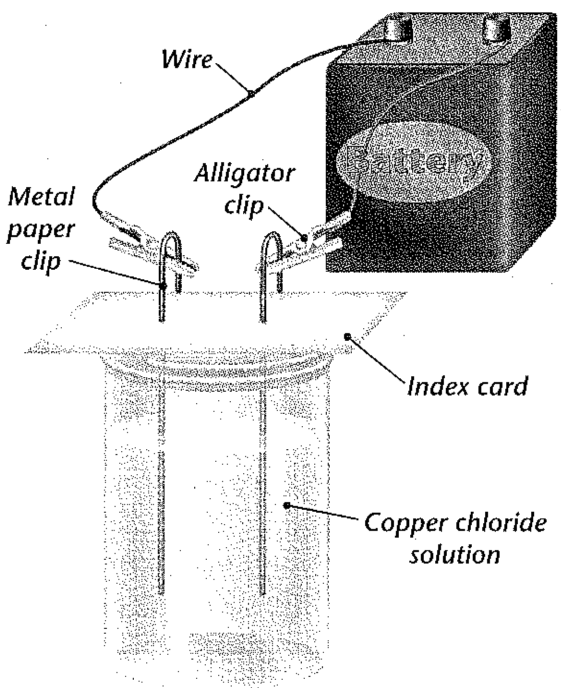
## Procedure

1. Straighten a paper clip into a hook shape. Push the long end through an index card until the hooked part touches the card.



2. Repeat Step 1 with another paper clip so that the clips are about 2–3 cm apart. The paper clips serve as your electrodes.
3. Pour enough copper chloride solution into a jar to cover at least half the length of the paper clips when the index card is set on top of the jar. **CAUTION:** *Copper chloride solution can be irritating to the skin and eyes. Do not touch it with your hands or get it in your mouth. The solution can stain your skin and clothes.*
4. Place the index card on top of the jar. If the straightened ends of the paper clips are not at least half-covered by the copper chloride solution, add more solution.

When the electric current is turned on, one electrode in the solution becomes coated with copper metal. At the same time, other materials form on the second electrode. In a laboratory, electrolysis yields only small amounts of copper metal. In industry, the isolation of copper from its ores happens on a huge scale and involves several complex steps. Because many copper compounds do not dissolve in water, the method of electrolysis used in the last step can vary.




5. Attach a wire to each pole of a battery. Attach the other ends of the wires to a separate paper clip. See the drawing. Prevent the paper clips from touching each other.
6. Predict what you think will happen if you allow the current to run 2–3 minutes. (*Hint:* What elements are present in the copper chloride solution?)
7. Let the setup run 2–3 minutes or until you see a deposit forming on one of the electrodes. Also look for bubbles.
8. Disconnect the wires. Remove the index card. Bring your face close to the jar and gently wave your hand toward your nose. Note any odor.
9. Note whether the color of the solution has changed since you began the procedure.
10. Note the color of the tips of the electrodes.
11. Discard the solution as directed by your teacher, and wash your hands.

## Analyze and Conclude

1. Make a labeled diagram of your experimental setup. Indicate which electrode is connected to the positive side of the battery and which is connected to the negative side.
2. On which electrode was the copper produced? On which electrode was the chlorine produced?
3. If the color of the solution changed, how can you explain the change?
4. Compare the properties of copper, chlorine, and copper chloride solution.
5. Describe the changes in matter that you observed. Classify them as physical changes or chemical changes.
6. **Apply** Using your observations from this lab as evidence, explain why you think copper chloride is a compound, not a mixture.

## More to Explore

Suppose you were to reconnect the wires with the positive and negative sides reversed. Predict how your results would differ under these conditions. With your teacher's permission, carry out the electrolysis with the connections reversed. Was your prediction correct?

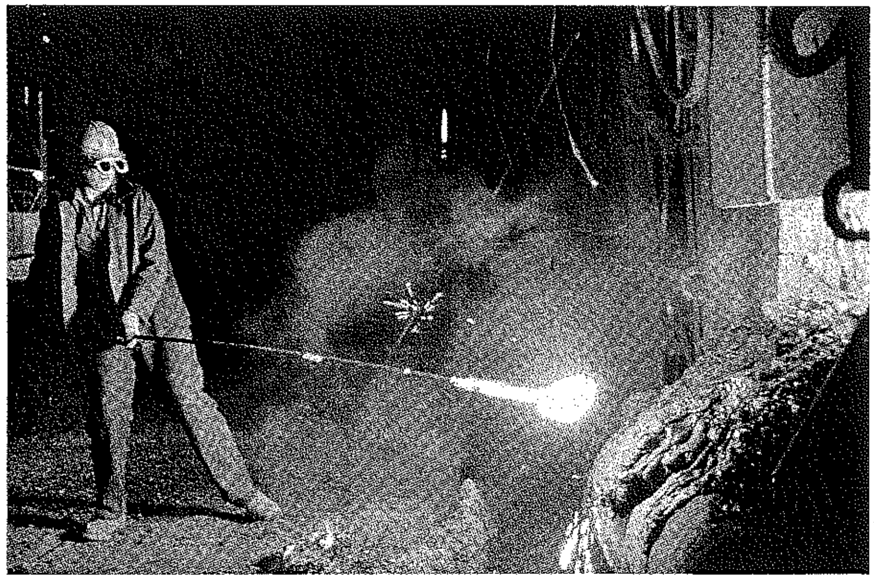


**Figure 15** Industry uses large-scale chemical reactions to produce useful materials. This blast furnace is used to react carbon with iron ore to produce iron metal. The source of the carbon is coke, a substance produced from coal.

## Iron and the Blast Furnace

Iron is another element that industry needs in huge amounts. Like copper, iron is usually found in an ore in the form of a compound. And also like copper, the element iron must be separated from its compounds by a chemical reaction.

Iron ores usually contain compounds formed of iron and oxygen. In order to release the iron, chunks of iron ore are placed in a hot fire along with coke, a source of carbon. In the intense heat of a blast furnace like the one in Figure 15, the carbon reacts with the oxygen. The element iron is left behind.

After leaving the blast furnace, iron is often combined with other materials to produce mixtures having specific properties. For example, iron may be combined with carbon and other metals to produce steel, which is stronger than iron alone. Adding chromium and nickel makes stainless steel, which resists rusting. Iron, copper, and gold are just three examples of useful elements that are extracted from Earth's surface.

## Section 4 Review

1. Describe how panning for gold takes advantage of a specific property of gold.
2. What kind of change must take place to remove an element from its compound? Explain.
3. What happens to the elements in iron ore when the ore is mixed with carbon and heated?
4. **Thinking Critically Making Judgments** Planet Earth contains a limited supply of all metals. Predict whether programs to recycle aluminum, iron, and other metals will become more important in the future.

CHAPTER PROJECT

***Check Your Progress***

Trade your written procedure and product samples with a new partner. Repeat this partner's procedure, following the directions as exactly as you can. Share your results with your partner. Think of ways to improve both your procedure and your partner's procedure to make them clearer to follow.

# CHAPTER 1 STUDY GUIDE

## Section 1 Describing Matter

**Key Ideas**

- Matter makes up everything in the universe. Matter can have a variety of properties.
- Each specific substance has its own set of properties. These properties can be used to identify the substance.
- Matter is made up of elements. Elements can be chemically combined in compounds. Elements and compounds may also be together as mixtures.
- Physical changes alter the form of a substance, but not its identity. Chemical changes result in one or more new substances.

**Key Terms**

| | | |
|---|---|---|
| chemistry | compound | physical change |
| element | formula | chemical change |
| atom | mixture | chemical reaction |
| symbol | | |

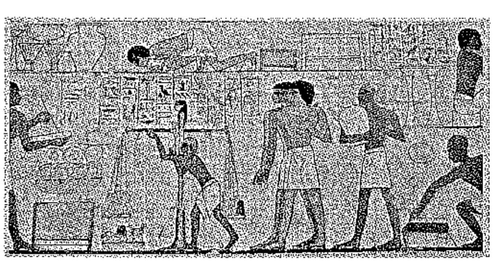
## Section 2 Measuring Matter

**Key Ideas**

- Mass is a measurement of how much matter an object contains. If you move an object away from Earth, its weight changes but its mass stays the same.
- The density of an object equals its mass divided by its volume. A unit of density is always a mass unit divided by a volume unit, such as grams per cubic centimeter ($g/cm^3$).

**Key Terms**

| | |
|---|---|
| weight | volume |
| mass | density |
| International System of Units (SI) | |



## Section 3 Particles of Matter

**Key Ideas**

- Atoms are the smallest particles of an element.
- Dalton stated that atoms are unbreakable, rigid spheres. He also said that atoms of different elements are different from one another.
- Atoms can be combined into molecules, which are held together by chemical bonds.

**Key Terms**

| | |
|---|---|
| chemical bond | molecule |

## Section 4 Elements From Earth

*INTEGRATING EARTH SCIENCE*

**Key Ideas**

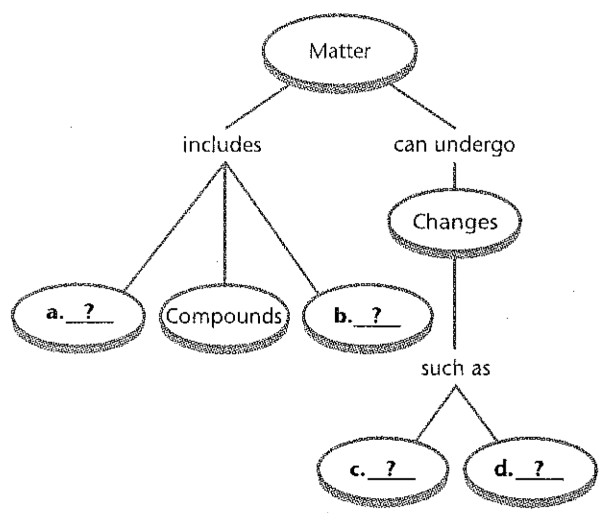
- Gold, which is usually found in nature as an element, can be separated from other materials because of its density.
- Earth contains deposits of many elements in the form of compounds. A chemical reaction is needed to remove an element from its compound.

**Key Terms**

| | |
|---|---|
| electrolysis | electrode |

## Organizing Information

**Concept Map** Copy the concept map about classifying matter onto a separate sheet of paper. Then complete the map and add a title. (For more on concept maps, see the Skills Handbook.)



## Reviewing Content

*For more review of key concepts, see the Interactive Student Tutorial CD-ROM.*

### Multiple Choice

*Choose the letter of the answer that best completes the statement or answers the question.*

1. The building blocks of matter are called
   **a.** mixtures. **b.** elements.
   **c.** compounds. **d.** properties.
2. A formula shows the ratio of elements in
   **a.** a mixture. **b.** matter.
   **c.** a compound. **d.** a chemical change.
3. The density of an object equals
   **a.** the product of its length, width, and height.
   **b.** its volume divided by its mass.
   **c.** the product of the mass and volume.
   **d.** its mass divided by its volume.
4. Dalton imagined atoms to be
   **a.** rigid, unbreakable spheres.
   **b.** all exactly alike.
   **c.** always joined together in compounds.
   **d.** of equal mass.
5. A method used to release iron metal from its ore involves
   **a.** heating the ore and carbon together.
   **b.** cooling the ore in an ice bath.
   **c.** breaking the ore into small pieces.
   **d.** panning.

### True or False

*If the statement is true, write true. If it is false, change the underlined word or words to make it true.*

6. <u>Compounds</u> are substances that cannot be broken down into other substances by any chemical means.
7. If you move an object from place to place in the universe, the <u>weight</u> of the object will stay the same.
8. Grams per milliliter (g/mL) is an example of a unit of <u>volume</u>.
9. One of Dalton's principles is that each element is made of its own kind of <u>atom</u>.
10. Useful amounts of copper can be isolated during a process called <u>electrolysis</u>.

## Checking Concepts

11. When a piece of paper is torn into two pieces, has it undergone a chemical change or a physical change? Explain.
12. How could you find the volume of a small rock, using only a graduated cylinder and water?
13. What can you infer about the density of a substance if a block of that substance floats in water?
14. How are atoms related to molecules in a sample of a compound?
15. **Writing to Learn** In a novel or short story, the author describes the properties of objects he or she is writing about. These details add interest to the story. Select at least six different kinds of objects. You might include objects from nature as well as objects made by people. List the properties of each object. Now use that list to write the first paragraph of a story.

## Thinking Critically

16. **Problem Solving** How can you show that salt water is a mixture and not a compound? First compare the properties of the solution to the properties of the individual components. Then come up with a plan to separate the solution into its components.
17. **Comparing and Contrasting** Compare and contrast atoms and molecules. What do the two kinds of particles have in common? How are they related? Give an example that shows this relationship.
18. **Applying Concepts** How can you use Dalton's atomic theory to explain why every sample of a particular substance has the same properties?
19. **Inferring** Solid gold has a greater density than liquid gold. What must happen to the volume of a given mass of solid gold when it becomes a liquid? Explain.

## Applying Skills

*Use the table below to answer Questions 20–22. The table lists the mass and volume of six coins.*

| Coin | Mass (g) | Volume ($cm^3$) |
|---|---|---|
| A | 3.1 | 0.41 |
| B | 4.0 | 0.50 |
| C | 8.6 | 1.2 |
| D | 8.0 | 0.95 |
| E | 9.8 | 1.1 |
| F | 5.0 | 0.67 |

**20. Calculating** Based on the data in the table, calculate the density of Coins A–F.

**21. Interpreting Data** In Altrusia, all coins are made of a mixture of copper and zinc that has a density of 8.42 g/$cm^3$. Which coins could be from Altrusia?

**22. Drawing Conclusions** The density of copper is 8.92 g/$cm^3$ and the density of zinc is 7.14 g/$cm^3$. If you assume that only copper and zinc were used to make the coins, can any of the coins be pure copper? Can any be pure zinc? Explain.

### Performance CHAPTER PROJECT Assessment

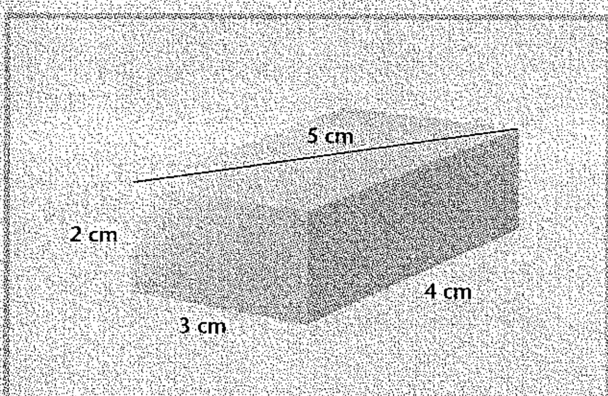
**Present Your Project** Work with your second partner to show the data each of you collected. The data should be presented so that other students can see whether your procedures produced similar results. Briefly present your procedure and results to the class.

**Reflect and Record** In your journal, record the results of your experiment and describe any conclusions you reached. Are you satisfied that your conclusions are accurate? If you could repeat the experiment, what improvements would you make to your procedure?

## Test Preparation

*Use these questions to prepare for standardized tests.*

*Use the diagram to answer Questions 23–26.*




Alexander found a solid block of an unknown material. He used a metric ruler to measure the size of the block. The measurements he recorded are shown in the diagram.

**23.** What is the volume of the block?
- **a.** 9 cm
- **b.** 24 $cm^2$
- **c.** 24 $cm^3$
- **d.** 60 $cm^3$

**24.** Which measurement shown in the diagram was not needed to find the volume of the box?
- **a.** length (4 cm)
- **b.** height (2 cm)
- **c.** width (3 cm)
- **d.** diagonal (5 cm)

**25.** Alexander knows that the density of the material from which the block is made is 2 g/$cm^3$. Knowing this, what is the mass of the block?
- **a.** 4.8 g
- **b.** 48 g
- **c.** 480 g
- **d.** 4,800 g

**26.** If the block could be molded into a flatter and longer shape, then the
- **a.** mass, volume, and density all would change.
- **b.** volume would change, but the mass and density would remain the same.
- **c.** mass and volume would change, but the density would remain the same.
- **d.** mass, volume, and density all would remain the same.