SECTION 1

What Is Matter?

What do you have in common with a toaster, a steaming bowl of soup, or a bright neon sign?

READING WARM-UP

Objectives

- Describe the two properties of all matter.
- Identify the units used to measure volume and mass.
- Compare mass and weight.
- Explain the relationship between mass and inertia.

Terms to Learn

matter	mass
volume	weight
meniscus	inertia

READING STRATEGY

Prediction Guide Before reading this section, write the title of each heading in this section. Next, under each heading, write what you think you will learn.

You are probably thinking that this is a trick question. It is hard to imagine that a person has anything in common with a kitchen appliance, hot soup, or a glowing neon sign.

Matter

From a scientific point of view, you have at least one characteristic in common with these things. You, the toaster, the bowl, the soup, the steam, the glass tubing of a neon sign, and the glowing gas are made of matter. But exactly what is matter? **Matter** is anything that has mass and takes up space. It's that simple! Everything in the universe that you can see is made up of some type of matter.

matter anything that has mass and takes up space

Matter and Volume

All matter takes up space. The amount of space taken up, or occupied, by an object is known as the object's **volume.** Your fingernails, the Statue of Liberty, the continent of Africa, and a cloud have volume. And because these things have volume, they cannot share the same space at the same time. Even the tiniest speck of dust takes up space. Another speck of dust cannot fit into that space without somehow bumping the first speck out of the way. **Figure 1** shows an example of how one object cannot share with another object the same space at the same time. Try the Quick Lab on the next page to see for yourself that matter takes up space.

volume a measure of the size of a body or region in three-dimensional space

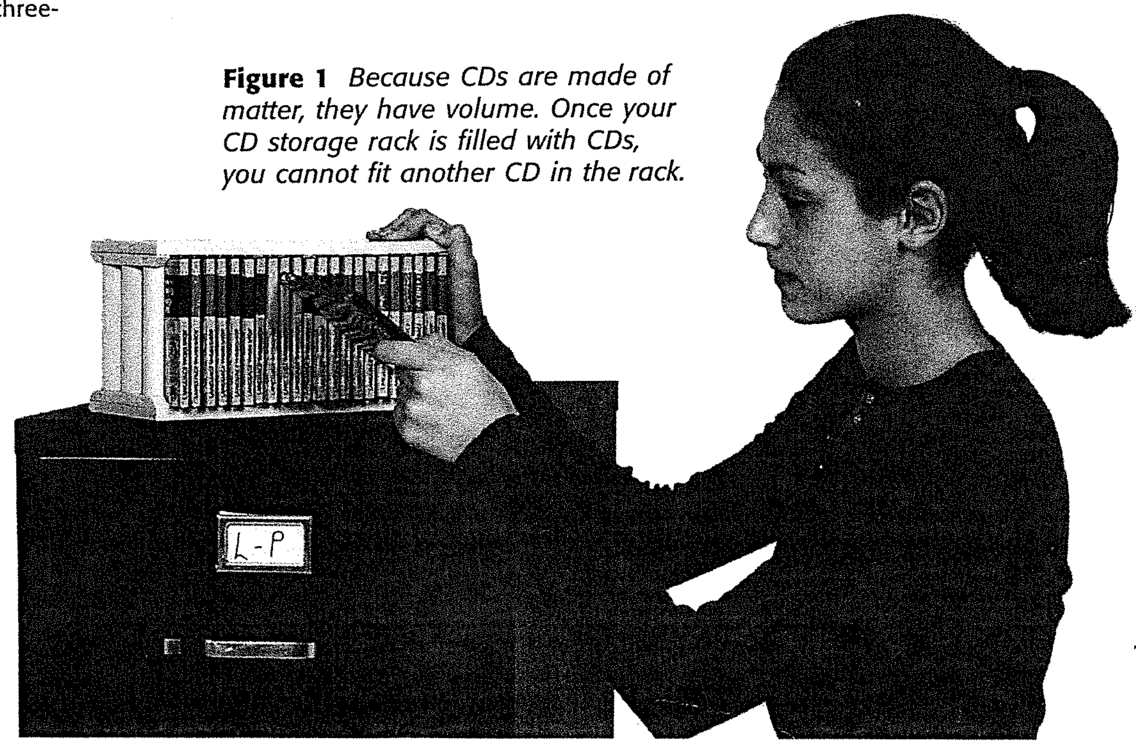


Figure 1 *Because CDs are made of matter, they have volume. Once your CD storage rack is filled with CDs, you cannot fit another CD in the rack.*

Quick Lab

Space Case

1. Crumple a **piece of paper.** Fit it tightly in the bottom of a **clear plastic cup** so that it won't fall out.
2. Turn the cup upside down. Lower the cup straight down into a **bucket** half-filled with **water.** Be sure that the cup is completely underwater.
3. Lift the cup straight out of the water. Turn the cup upright, and observe the paper. Record your observations.
4. Use the point of a **pencil** to punch a small hole in the bottom of the cup. Repeat steps 2 and 3.
5. How do the results show that air has volume? Explain your answer.

Liquid Volume

Lake Erie, the smallest of the Great Lakes, has a volume of approximately 483 trillion (that's 483,000,000,000,000) liters of water. Can you imagine that much water? Think of a 2-liter bottle of soda. The water in Lake Erie could fill more than 241 trillion 2-liter soda bottles. That's a lot of water! On a smaller scale, a can of soda has a volume of only 355 milliliters, which is about one-third of a liter. You can check the volume of the soda by using a large measuring cup from your kitchen.

Liters (L) and milliliters (mL) are the units used most often to express the volume of liquids. The volume of any amount of liquid, from one raindrop to a can of soda to an entire ocean, can be expressed in these units.

Reading Check **What are two units used to measure volume?** (*See the Appendix for answers to Reading Checks.*)

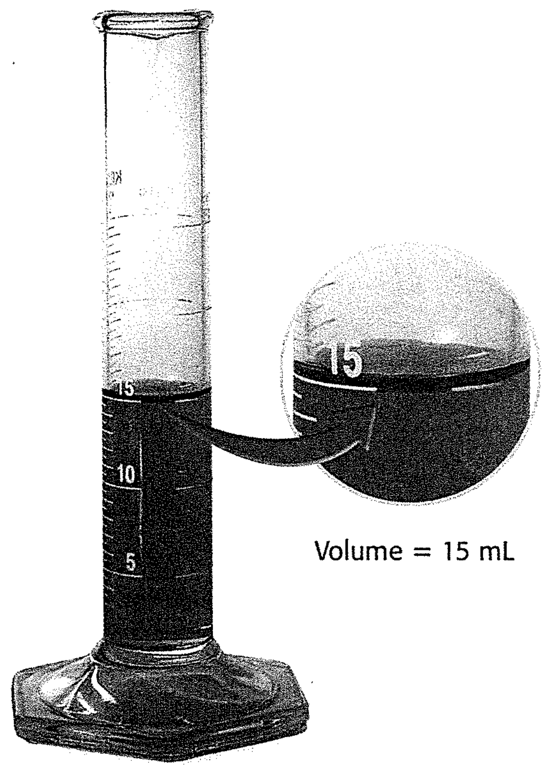


Figure 2 *To measure volume correctly, read the scale of the lowest part of the meniscus (as shown) at eye level.*

Measuring the Volume of Liquids

In your science class, you'll probably use a graduated cylinder instead of a measuring cup to measure the volume of liquids. Graduated cylinders are used to measure the liquid volume when accuracy is important. The surface of a liquid in any container, including a measuring cup or a large beaker, is curved. The curve at the surface of a liquid is called a **meniscus** (muh NIS kuhs). To measure the volume of most liquids, such as water, you must look at the bottom of the meniscus, as shown in **Figure 2.** Note that you may not be able to see a meniscus in a large beaker. The meniscus looks flat because the liquid is in a wide container.

meniscus the curve at a liquid's surface by which one measures the volume of the liquid

Volume of a Regularly Shaped Solid Object

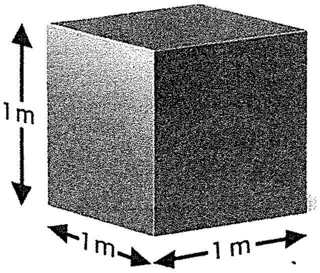


Figure 3 *A cubic meter (1 m^3) is a cube that has a length, width, and height of 1 m.*

The volume of any solid object is expressed in cubic units. The word *cubic* means "having three dimensions." In science, cubic meters (m^3) and cubic centimeters (cm^3) are the units most often used to express the volume of solid things. The 3 in these unit symbols shows that three quantities, or dimensions, were multiplied to get the final result. You can see the three dimensions of a cubic meter in **Figure 3.** There are formulas to find the volume of regularly shaped objects. For example, to find the volume of a cube or a rectangular object, multiply the length, width, and height of the object, as shown in the following equation:

$$volume = length \times width \times height$$

Volume of an Irregularly Shaped Solid Object

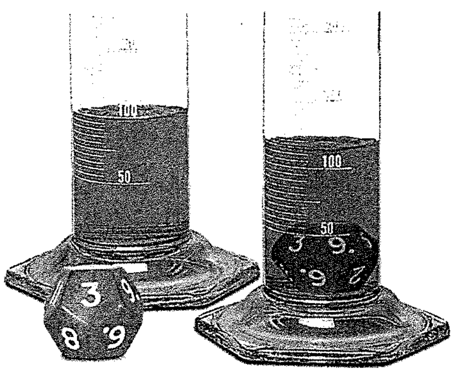


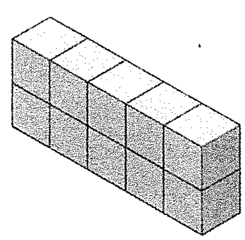
Figure 4 *The 12-sided object displaced 15 mL of water. Because 1 mL = 1 cm^3, the volume of the object is 15 cm^3.*

How do you find the volume of a solid that does not have a regular shape? For example, to find the volume of a 12-sided object, you cannot use the equation given above. But you can measure the volume of a solid object by measuring the volume of water that the object displaces. In **Figure 4,** when a 12-sided object is added to the water in a graduated cylinder, the water level rises. The volume of water displaced by the object is equal to its volume. Because 1 mL is equal to 1 cm^3, you can express the volume of the water displaced by the object in cubic centimeters. Although volumes of liquids can be expressed in cubic units, volumes of solids should not be expressed in liters or milliliters.

Reading Check **Explain how you would measure the volume of an apple.**

MATH FOCUS

Volume of a Rectangular Solid What is the volume of a box that has a length of 5 cm, a width of 1 cm, and a height of 2 cm?



Step 1: Write the equation for volume.

$$volume = length \times width \times height$$

Step 2: Replace the variables with the measurements given to you, and solve.

$$volume = 5\ cm \times 1\ cm \times 2\ cm = 10\ cm^3$$

Now It's Your Turn

1. A book has a length of 25 cm, a width of 18 cm, and a height of 4 cm. What is its volume?
2. What is the volume of a suitcase that has a length of 95 cm, a width of 50 cm, and a height of 20 cm?
3. A CD case is 14.2 cm long, 12.4 cm wide, and 1 cm deep. What is its volume?

Matter and Mass

Another characteristic of all matter is mass. **Mass** is the amount of matter in an object. For example, you and a peanut are made of matter. But you are made of more matter than a peanut is, so you have more mass. The mass of an object is the same no matter where in the universe the object is located. The only way to change the mass of an object is to change the amount of matter that makes up the object.

mass a measure of the amount of matter in an object

weight a measure of the gravitational force exerted on an object; its value can change with the location of the object in the universe

The Difference Between Mass and Weight

The terms *mass* and *weight* are often used as though they mean the same thing, but they don't. **Weight** is a measure of the gravitational (GRAV i TAY shuh nuhl) force exerted on an object. Gravitational force keeps objects on Earth from floating into space. The gravitational force between an object and the Earth depends partly on the object's mass. The more mass an object has, the greater the gravitational force on the object and the greater the object's weight. But an object's weight can change depending on its location in the universe. An object would weigh less on the moon than it does on Earth because the moon has less gravitational force than Earth does. **Figure 5** explains the differences between mass and weight.

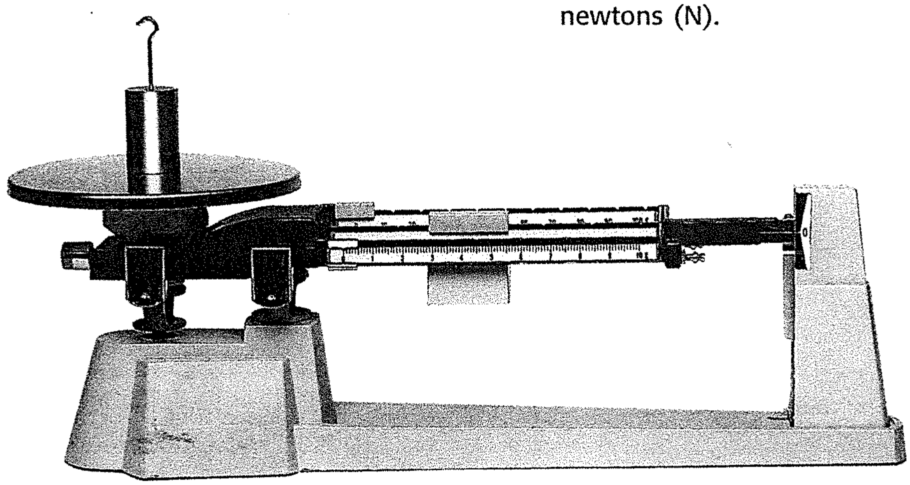
Figure 5 **Differences Between Mass and Weight**

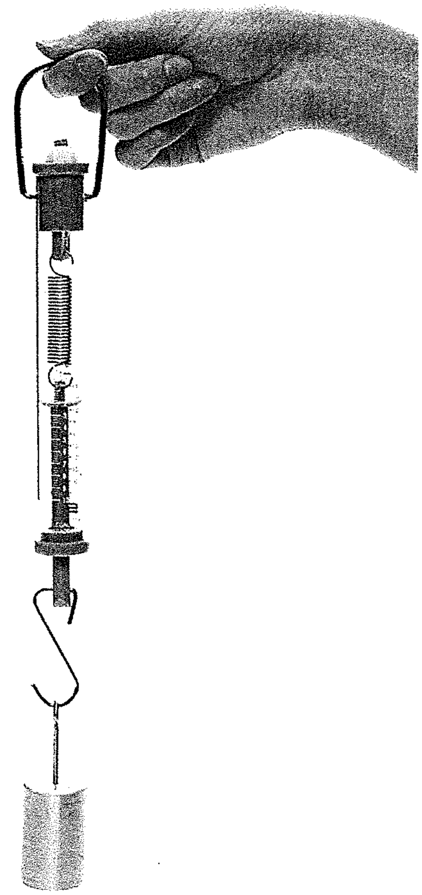
Mass

- Mass is a measure of the amount of matter in an object.
- Mass is always constant for an object no matter where the object is located in the universe.
- Mass is measured by using a balance (shown below).
- Mass is expressed in kilograms (kg), grams (g), and milligrams (mg).

Weight

- Weight is a measure of the gravitational force on an object.
- Weight varies depending on where the object is in relation to the Earth (or any large body in the universe).
- Weight is measured by using a spring scale (shown at right).
- Weight is expressed in newtons (N).





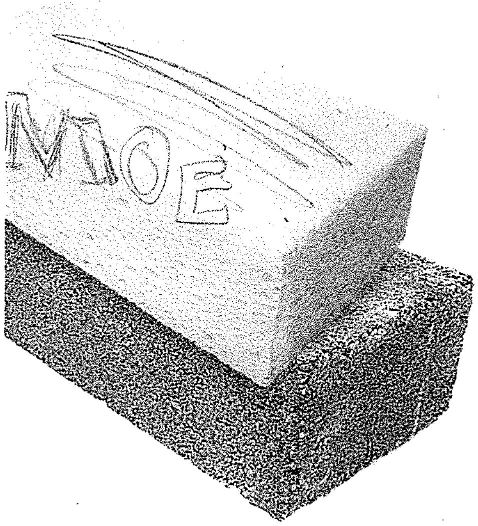


Figure 6 *The brick and the sponge take up the same amount of space. But the brick has more matter in it, so its mass—and thus its weight—is greater.*

Measuring Mass and Weight

The brick and the sponge in **Figure 6** have the same volume. But because the brick has more mass, a greater gravitational force is exerted on the brick than on the sponge. As a result, the brick weighs more than the sponge.

The SI unit of mass is the kilogram (kg), but mass is often expressed in grams (g) and milligrams (mg), too. These units can be used to express the mass of any object in the universe.

Weight is a measure of gravitational force and is expressed in the SI unit of force, the *newton* (N). One newton is about equal to the weight of an object that has a mass of 100 g on Earth. So, if you know the mass of an object, you can calculate the object's weight on Earth. Weight is a good estimate of the mass of an object because, on Earth, gravity doesn't change.

Reading Check **What units are often used to measure mass?**

Inertia

inertia the tendency of an object to resist being moved or, if the object is moving, to resist a change in speed or direction until an outside force acts on the object

Imagine kicking a soccer ball that has the mass of a bowling ball. It would be not only painful but also very difficult to get the ball moving in the first place! The reason is inertia (in UHR shuh). **Inertia** is the tendency of an object to resist a change in motion. So, an object at rest will remain at rest until something causes the object to move. Also, a moving object will keep moving at the same speed and in the same direction unless something acts on the object to change its speed or direction.

MATH FOCUS

Converting Mass to Weight A student has a mass of 45,000 g. How much does this student weigh in newtons?

Step 1: Write the information given to you.

$$45{,}000 \text{ g}$$

Step 2: Write the conversion factor to change grams into newtons.

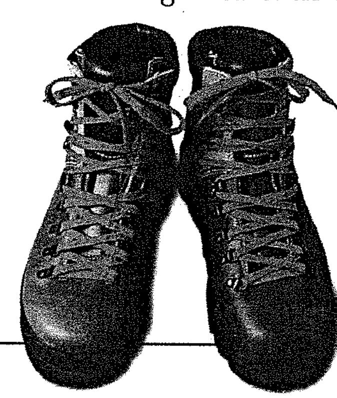
$$1 \text{ N} = 100 \text{ g}$$

Step 3: Write the equation so that grams will cancel.

$$45{,}000 \text{ g} \times \frac{1 \text{ N}}{100 \text{ g}} = 450 \text{ N}$$

Now It's Your Turn

1. What is the weight of a car that has a mass of 1,362,000 g?
2. Your pair of boots has a mass of 850 g. If each boot has exactly the same mass, what is the weight of each boot?



Mass: The Measure of Inertia

Mass is a measure of inertia. An object that has a large mass is harder to get moving and harder to stop than an object that has less mass. The reason is that the object with the large mass has greater inertia. For example, imagine that you are going to push a grocery cart that has only one potato in it. Pushing the cart is easy because the mass and inertia are small. But suppose the grocery cart is stacked with potatoes, as in **Figure 7.** Now the total mass—and the inertia—of the cart full of potatoes is much greater. It will be harder to get the cart moving. And once the cart is moving, stopping the cart will be harder.

Figure 7 *Because of inertia, moving a cart full of potatoes is more difficult than moving a cart that is empty.*

SECTION Review

Summary

- Two properties of matter are volume and mass.
- Volume is the amount of space taken up by an object.
- The SI unit of volume is the liter (L).
- Mass is the amount of matter in an object.
- The SI unit of mass is the kilogram (kg).
- Weight is a measure of the gravitational force on an object, usually in relation to the Earth.
- Inertia is the tendency of an object to resist being moved or, if the object is moving, to resist a change in speed or direction. The more massive an object is, the greater its inertia.

Using Key Terms

1. Use the following terms in the same sentence: *volume* and *meniscus*.
2. In your own words, write a definition for each of the following terms: *mass, weight,* and *inertia*.

Understanding Key Ideas

3. Which of the following is matter?
   - **a.** dust
   - **b.** the moon
   - **c.** strand of hair
   - **d.** All of the above
4. A graduated cylinder is used to measure
   - **a.** volume.
   - **b.** weight.
   - **c.** mass.
   - **d.** inertia.
5. The volume of a solid is measured in
   - **a.** liters.
   - **b.** grams.
   - **c.** cubic centimeters.
   - **d.** All of the above
6. Mass is measured in
   - **a.** liters.
   - **b.** centimeters.
   - **c.** newtons.
   - **d.** kilograms.
7. Explain the relationship between mass and inertia.

Math Skills

8. [illegible] of gold is placed in a graduated cylinder that contains 80 mL of water. The water level rises to 225 mL after the nugget is added to the cylinder. What is the volume of the gold nugget?
9. One newton equals about 100 g on Earth. How many newtons would a football weigh if it had a mass of 400 g?

Critical Thinking

10. **Identifying Relationships** Do objects with large masses always have large weights? Explain.
11. **Applying Concepts** Would an elephant weigh more or less on the moon than it would weigh on Earth? Explain your answer.

SECTION 2

Physical Properties

Have you ever played the game 20 Questions? The goal of this game is to figure out what object another person is thinking of by asking 20 yes/no questions or less.

READING WARM-UP

Objectives

- Identify six examples of physical properties of matter.
- Describe how density is used to identify substances.
- List six examples of physical changes.
- Explain what happens to matter during a physical change.

Terms to Learn

physical property
density
physical change

READING STRATEGY

Mnemonics As you read this section, create a mnemonic device to help you remember examples of physical properties.

If you can't figure out the object's identity after asking 20 questions, you may not be asking the right kinds of questions. What kinds of questions should you ask? You may want to ask questions about the physical properties of the object. Knowing the properties of an object can help you find out what it is.

Physical Properties

The questions in **Figure 1** help someone gather information about color, odor, mass, and volume. Each piece of information is a physical property of matter. A **physical property** of matter can be observed or measured without changing the matter's identity. For example, you don't have to change an apple's identity to see its color or to measure its volume.

Other physical properties, such as magnetism, the ability to conduct electric current, strength, and flexibility, can help someone identify how to use a substance. For example, think of a scooter with an electric motor. The magnetism produced by the motor is used to convert energy stored in a battery into energy that will turn the wheels.

Reading Check **List four physical properties.** (*See the Appendix for answers to Reading Checks.*)

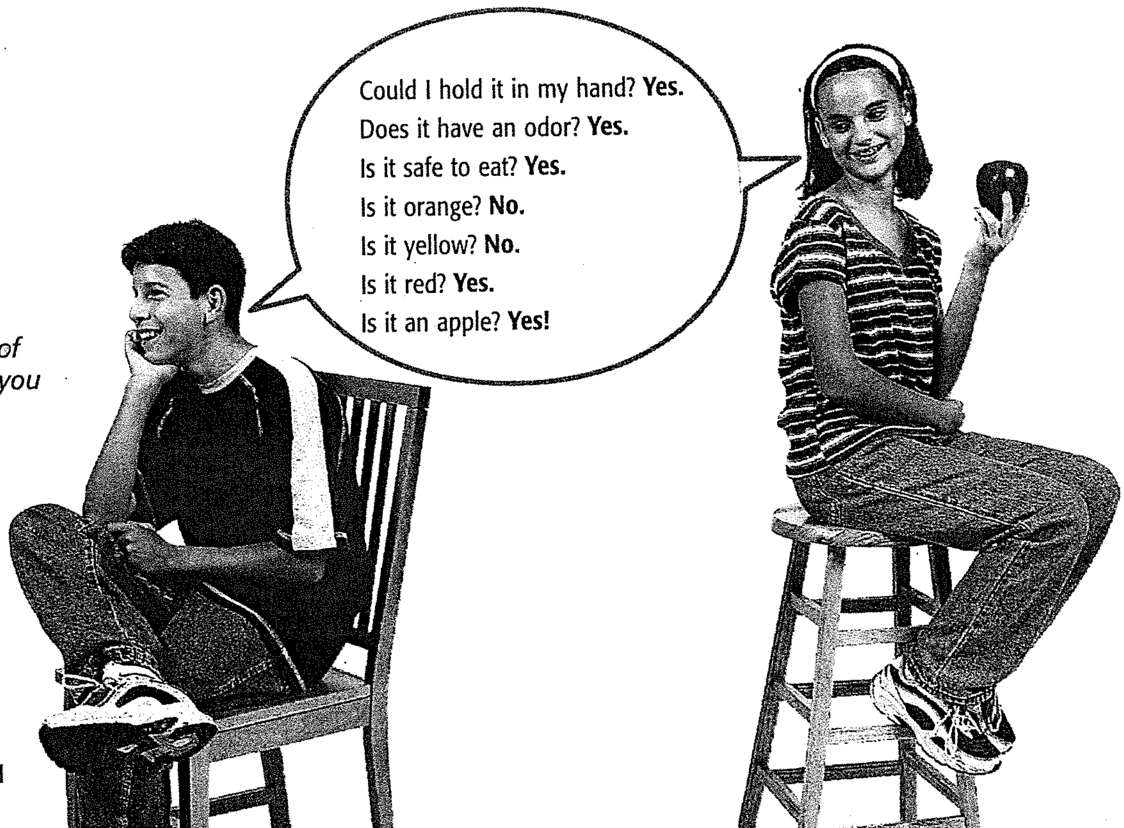
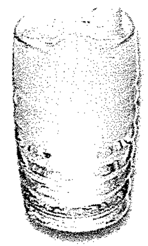


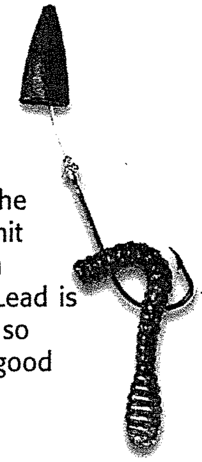
Figure 1 *Asking questions about the physical properties of an object can help you identify it.*

Figure 2 **Examples of Physical Properties**

Thermal conductivity (KAHN duhk TIV uh tee) is the rate at which a substance transfers heat. Plastic foam is a poor conductor.

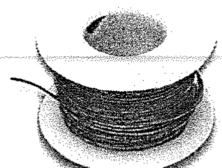


State is the physical form in which a substance exists, such as a solid, liquid, or gas. Ice is water in the solid state.

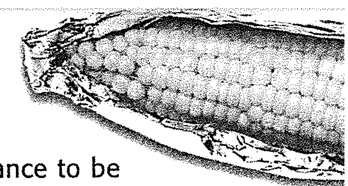


Density is the mass per unit volume of a substance. Lead is very dense, so it makes a good sinker for a fishing line.

Solubility (SAHL yoo BIL uh tee) is the ability of a substance to dissolve in another substance. Flavored drink mix dissolves in water.



Ductility (duhk TIL uh tee) is the ability of a substance to be pulled into a wire. Copper is often used to make wiring because it is ductile.



Malleability (MAL ee uh BIL uh tee) is the ability of a substance to be rolled or pounded into thin sheets. Aluminum can be rolled into sheets to make foil.

Identifying Matter

You use physical properties every day. For example, physical properties help you determine if your socks are clean (odor), if your books will fit into your backpack (volume), or if your shirt matches your pants (color). **Figure 2** gives more examples of physical properties.

physical property a characteristic of a substance that does not involve a chemical change, such as density, color, or hardness

density the ratio of the mass of a substance to the volume of the substance

Density

Density is a physical property that describes the relationship between mass and volume. **Density** is the amount of matter in a given space, or volume. A golf ball and a table-tennis ball, such as those in **Figure 3**, have similar volumes. But a golf ball has more mass than a table-tennis ball does. So, the golf ball has a greater density.

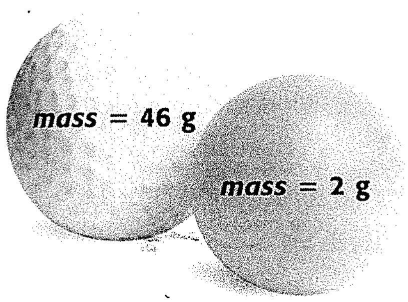


Figure 3 *A golf ball is denser than a table-tennis ball because the golf ball contains more matter in a similar volume.*

Liquid Layers

Figure 4 *This graduated cylinder contains six liquids. From top to bottom, they are corn oil, water, shampoo, dish detergent, antifreeze, and maple syrup.*

What do you think causes the liquid in **Figure 4** to look the way it does? Is it trick photography? No, it is differences in density! There are six liquids in the graduated cylinder. Each liquid has a different density. If the liquids are carefully poured into the cylinder, they can form six layers because of the differences in density. The densest layer is on the bottom. The least dense layer is on top. The order of the layers shows the order of increasing density. Yellow is the least dense, followed by the colorless layer, red, blue, green, and brown (the densest).

Density of Solids

Which would you rather carry around all day: a kilogram of lead or a kilogram of feathers? At first, you might say feathers. But both the feathers and the lead have the same mass, just as the cotton balls and the tomatoes have the same mass, as shown in **Figure 5.** So, the lead would be less awkward to carry around than the feathers would. The feathers are much less dense than the lead. So, it takes a lot of feathers to equal the same mass of lead.

Knowing the density of a substance can also tell you if the substance will float or sink in water. If the density of an object is less than the density of water, the object will float. Likewise, a solid object whose density is greater than the density of water will sink when the object is placed in water.

Reading Check **What will happen to an object placed in water if the object's density is less than water's density?**

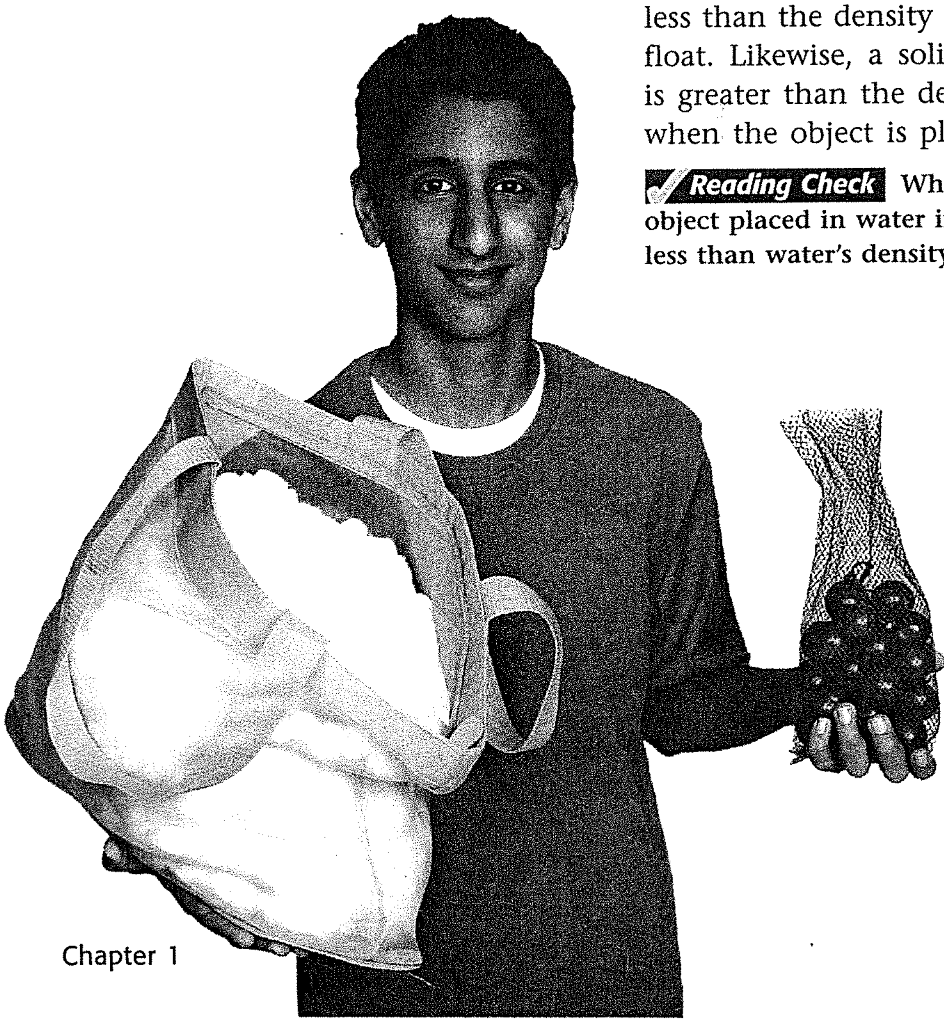


Figure 5 *The cotton balls and the tomatoes have the same mass. But cotton is much less dense than the tomatoes.*

Solving for Density

To find an object's density (D), first measure its mass (m) and volume (V). Then, use the equation below.

$$D = \frac{m}{V}$$

Units for density consist of a mass unit divided by a volume unit. Some units for density are g/cm^3, g/mL, kg/m^3, and kg/L. Remember that the volume of a solid is often given in cubic centimeters or cubic meters. So, the density of a solid should be given in units of g/cm^3 or kg/m^3.

Using Density to Identify Substances

Density is a useful physical property for identifying substances. Each substance has a density that differs from the densities of other substances. And the density of a substance is always the same at a given temperature and pressure. Look at **Table 1** to compare the densities of several common substances.

SCHOOL to HOME

Twenty Questions

Play a game of 20 Questions with a parent. One person will think of an object, and the other person will ask yes/no questions about it. Write the questions in your **science journal** as you play. Put a check mark next to the questions asked about physical properties. When the object is identified or when the 20 questions are up, switch roles.

ACTIVITY

Table 1 Densities of Common Substances*

Substance	Density* (g/cm^3)	Substance	Density* (g/cm^3)
Helium (gas)	0.00001663	Zinc (solid)	7.13
Oxygen (gas)	0.001331	Silver (solid)	10.50
Water (liquid)	1.00	Lead (solid)	11.35
Pyrite (solid)	5.02	Mercury (liquid)	13.55

*at 20°C and 1.0 atm

MATH FOCUS

Calculating Density What is the density of an object whose mass is 25 g and whose volume is 10 cm^3?

Step 1: Write the equation for density.

$$D = \frac{m}{V}$$

Step 2: Replace m and V with the measurements given in the problem, and solve.

$$D = \frac{25 \text{ g}}{10 \text{ cm}^3} = 2.5 \text{ g/cm}^3$$

The equation for density can also be rearranged to find mass and volume, as shown.

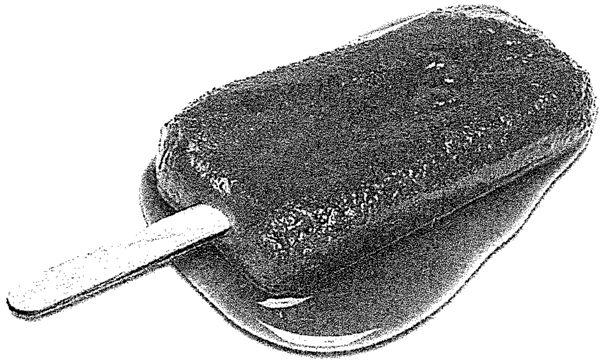
$m = D \times V$ (Rearrange by multiplying by V.)

$V = \frac{m}{D}$ (Rearrange by dividing by D.)

Now It's Your Turn

1. Find the density of a substance that has a mass of 45 kg and a volume of 43 m^3. (Hint: Make sure your answer's units are units of density.)
2. Suppose you have a lead ball whose mass is 454 g. What is the ball's volume? (Hint: Use **Table 1** above.)
3. What is the mass of a 15 mL sample of mercury?

Figure 6 Examples of Physical Changes



Changing from a solid to a liquid is a physical change. All changes of state are physical changes.

This aluminum can has gone through the physical change of being crushed. The properties of the can are the same.

Physical Changes Do Not Form New Substances

physical change a change of matter from one form to another without a change in chemical properties

A **physical change** is a change that affects one or more physical properties of a substance. Imagine that a piece of silver is pounded and molded into a heart-shaped pendant. This change is a physical one because only the shape of the silver has changed. The piece of silver is still silver. Its properties are the same. **Figure 6** shows more examples of physical changes.

Reading Check What is a physical change?

Examples of Physical Changes

Freezing water to make ice cubes and sanding a piece of wood are examples of physical changes. These changes do not change the identities of the substances. Ice is still water. And sawdust is still wood. Another interesting physical change takes place when certain substances dissolve in other substances. For example, when you dissolve sugar in water, the sugar seems to disappear. But if you heat the mixture, the water evaporates. Then, you will see that the sugar is still there. The sugar went through a physical change when it dissolved.

CONNECTION TO Geology

WRITING SKILL **Erosion** Erosion of soil is a physical change. Soil erodes when wind and water move soil from one place to another. Research the history of the Grand Canyon. Write a one-page report about how erosion formed the Grand Canyon.

Matter and Physical Changes

Physical changes do not change the identity of the matter involved. A stick of butter can be melted and poured over a bowl of popcorn, as shown in **Figure 7.** Although the shape of the butter has changed, the butter is still butter, so a physical change has occurred. In the same way, if you make a figure from a lump of clay, you change the clay's shape and cause a physical change. But the identity of the clay does not change. The properties of the figure are the same as those of the lump of clay.

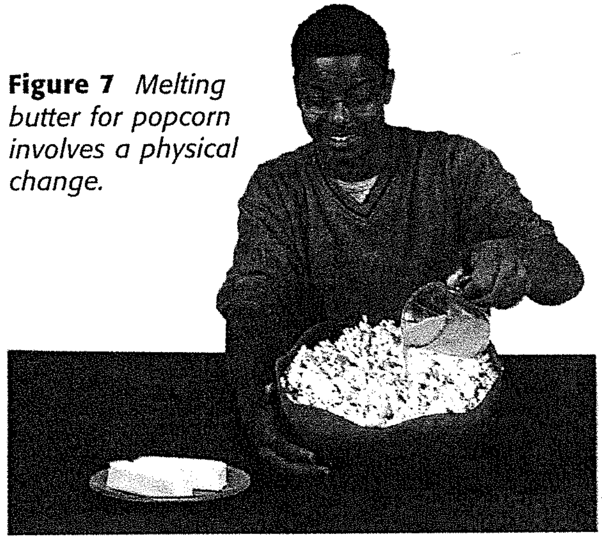


Figure 7 *Melting butter for popcorn involves a physical change.*

SECTION Review

Summary

- Physical properties of matter can be observed without changing the identity of the matter.
- Examples of physical properties are conductivity, state, malleability, ductility, solubility, and density.
- Density is the amount of matter in a given space.
- Density is used to identify substances because the density of a substance is always the same at a given pressure and temperature.
- When a substance undergoes a physical change, its identity stays the same.
- Examples of physical changes are freezing, cutting, bending, dissolving, and melting.

Using Key Terms

1. Use each of the following terms in a separate sentence: *physical property* and *physical change.*

Understanding Key Ideas

2. The units of density for a rectangular piece of wood are
   a. grams per milliliter.
   b. cubic centimeters.
   c. kilograms per liter.
   d. grams per cubic centimeter.
3. Explain why a golf ball is heavier than a table-tennis ball even though the balls are the same size.
4. Describe what happens to a substance when it goes through a physical change.
5. Identify six examples of physical properties.
6. List six physical changes that matter can go through.

Math Skills

7. What is the density of an object that has a mass of 350 g and a volume of 95 cm^3? Would this object float in water? Explain.
8. The density of an object is 5 g/cm^3, and the volume of the object is 10 cm^3. What is the mass of the object?

Critical Thinking

9. **Applying Concepts** How can you determine that a coin is not pure silver if you know the mass and volume of the coin?
10. **Identifying Relationships** What physical property do the following substances have in common: water, oil, mercury, and alcohol?
11. **Analyzing Processes** Explain how you would find the density of an unknown liquid if you have all of the laboratory equipment that you need.

SCILINKS. NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Describing Matter; Physical Changes
SciLinks code: HSM0391; HSM1142

SECTION 3

Chemical Properties

How would you describe a piece of wood before and after it is burned? Has it changed color? Does it have the same texture? The original piece of wood changed, and physical properties alone can't describe what happened to it.

READING WARM-UP

Objectives

- Describe two examples of chemical properties.
- Explain what happens during a chemical change.
- Distinguish between physical and chemical changes.

Terms to Learn

chemical property
chemical change

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

Chemical Properties

Physical properties are not the only properties that describe matter. **Chemical properties** describe matter based on its ability to change into new matter that has different properties. For example, when wood is burned, ash and smoke are created. These new substances have very different properties than the original piece of wood had. Wood has the chemical property of flammability. *Flammability* is the ability of a substance to burn. Ash and smoke cannot burn, so they have the chemical property of nonflammability.

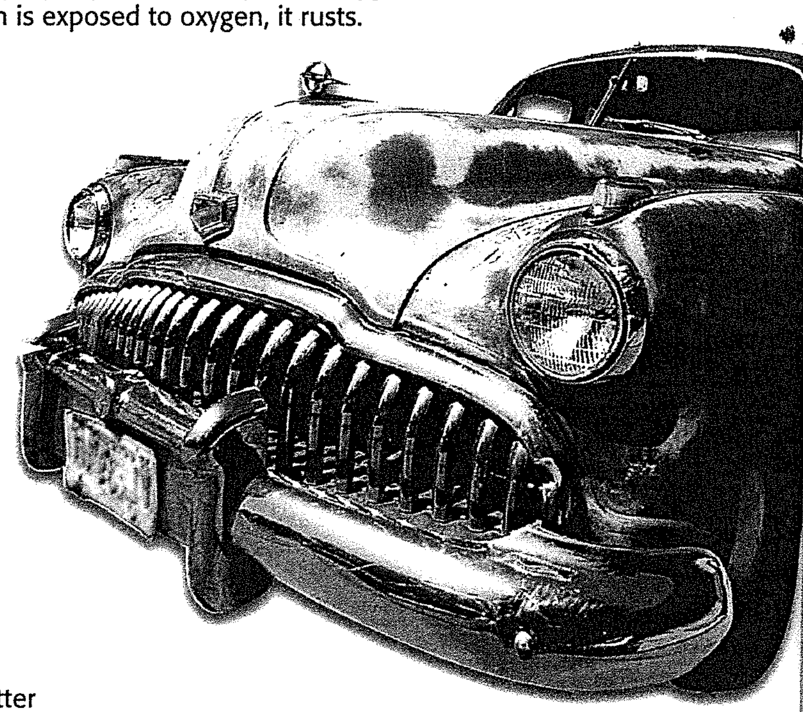
Another chemical property is reactivity. *Reactivity* is the ability of two or more substances to combine and form one or more new substances. The photo of the old car in **Figure 1** illustrates reactivity and nonreactivity.

Reading Check **What does the term *reactivity* mean?** *(See the Appendix for answers to Reading Checks.)*

chemical property a property of matter that describes a substance's ability to participate in chemical reactions

Figure 1 **Reactivity with Oxygen**

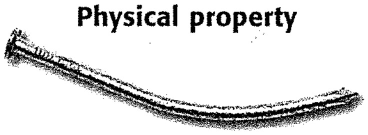
The iron used in this old car has the chemical property of **reactivity with oxygen**. When iron is exposed to oxygen, it rusts.



The bumper on this car still looks new because it is coated with chromium. Chromium has the chemical property of **nonreactivity with oxygen.**

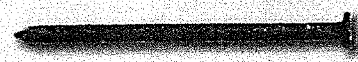
Figure 2 **Physical Versus Chemical Properties**

Physical property

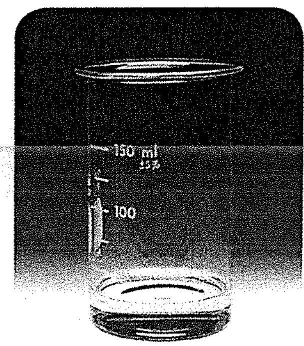


Shape Bending an iron nail will change its shape.

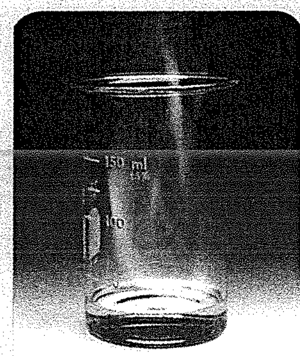
Chemical property



Reactivity with Oxygen An iron nail can react with oxygen in the air to form iron oxide, or rust.



State Rubbing alcohol is a clear liquid at room temperature.



Flammability Rubbing alcohol is able to burn easily.

Comparing Physical and Chemical Properties

How do you tell a physical property from a chemical property? You can observe physical properties without changing the identity of the substance. For example, you can find the density and hardness of wood without changing anything about the wood.

Chemical properties, however, aren't as easy to observe. For example, you can see that wood is flammable only while it is burning. And you can observe that gold is nonflammable only when it won't burn. But a substance always has chemical properties. A piece of wood is flammable even when it's not burning. **Figure 2** shows examples of physical and chemical properties.

Characteristic Properties

The properties that are most useful in identifying a substance are *characteristic properties*. These properties are always the same no matter what size the sample is. Characteristic properties can be physical properties, such as density and solubility, as well as chemical properties, such as flammability and reactivity. Scientists rely on characteristic properties to identify and classify substances.

CONNECTION TO Social Studies

WRITING SKILL **The Right Stuff** When choosing materials to use in manufacturing, you must make sure their properties are suitable for their uses. For example, false teeth can be made from acrylic plastic, porcelain, or gold. According to legend, George Washington wore false teeth made of wood. Do research and find what Washington's false teeth were really made of. In your **science journal,** write a paragraph about what you have learned. Include information about the advantages of the materials used in modern false teeth.

Quick Lab

Changing Change

1. Place a folded **paper towel** in a small **pie plate.**
2. Pour **vinegar** into the pie plate until the entire paper towel is damp.
3. Place three shiny **pennies** on top of the paper towel.
4. Put the pie plate in a safe place. Wait 24 hours.
5. Describe and explain the change that took place.

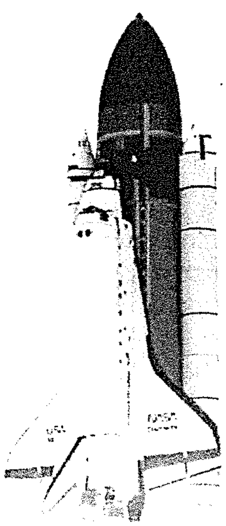
Chemical Changes and New Substances

A **chemical change** happens when one or more substances are changed into new substances that have new and different properties. Chemical changes and chemical properties are not the same. Chemical properties of a substance describe which chemical changes will occur and which chemical changes will not occur. But chemical changes are the process by which substances actually change into new substances. You can learn about the chemical properties of a substance by looking at the chemical changes that take place.

You see chemical changes more often than you may think. For example, a chemical reaction happens every time a battery is used. Chemicals failing to react results in a dead battery. Chemical changes also take place within your body when the food you eat is digested. **Figure 3** describes other examples of chemical changes.

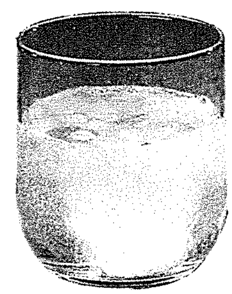
Reading Check How does a chemical change differ from a chemical property?

Figure 3 **Examples of Chemical Changes**

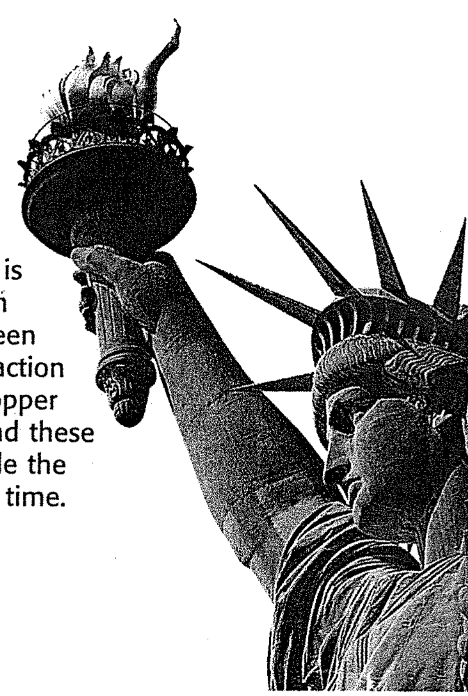


The **hot gas** formed when hydrogen and oxygen join to make water helps blast the space shuttle into orbit.

Soured milk smells bad because bacteria have formed new substances in the milk.



Effervescent tablets bubble when the citric acid and baking soda in them react in water.



The **Statue of Liberty** is made of orange-brown copper but it looks green from the metal's interaction with moist air. New copper compounds formed and these chemical changes made the statue turn green over time.

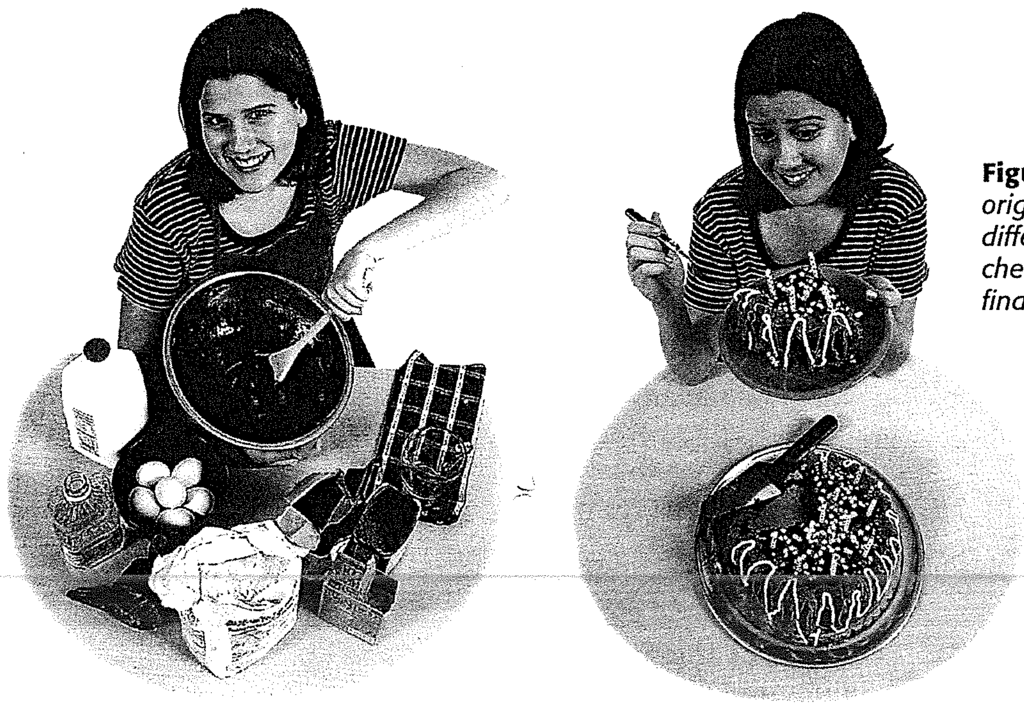


Figure 4 *Each of the original ingredients has different physical and chemical properties than the final product, the cake, does!*

What Happens During a Chemical Change?

A fun way to see what happens during chemical changes is to bake a cake. You combine eggs, flour, sugar, and other ingredients, as shown in **Figure 4.** When you bake the batter, you end up with something completely different. The heat of the oven and the interaction of the ingredients cause a chemical change. The result is a cake that has properties that differ from the properties of the ingredients.

chemical change a change that occurs when one or more substances change into entirely new substances with different properties

Signs of Chemical Changes

Look back at **Figure 3.** In each picture, at least one sign indicates a chemical change. Other signs that indicate a chemical change include a change in color or odor, production of heat, fizzing and foaming, and sound or light being given off.

In the cake example, you would smell the cake as it baked. You would also see the batter rise and begin to brown. When you cut the finished cake, you would see the air pockets made by gas bubbles that formed in the batter. These signs show that chemical changes have happened.

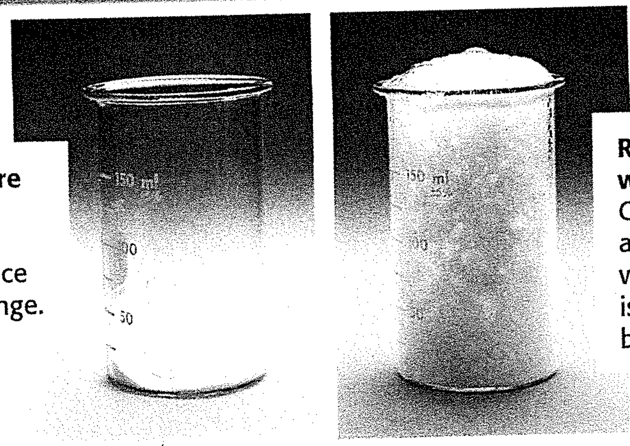
INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in keyword **HP5MATW.**

Matter and Chemical Changes

Chemical changes change the identity of the matter involved. So, most of the chemical changes that occur in your daily life, such as a cake baking, would be hard to reverse. Imagine trying to unbake a cake. However, some chemical changes can be reversed by more chemical changes. For example, the water formed in the space shuttle's rockets could be split into hydrogen and oxygen by using an electric current.

Figure 5 **Physical and Chemical Changes**



Change in Texture Grinding baking soda into a fine, powdery substance is a physical change.

Reactivity with Vinegar Gas bubbles are produced when vinegar is poured into baking soda.

Physical Versus Chemical Changes

The most important question to ask when trying to decide if a physical or chemical change has happened is, Did the composition change? The *composition* of an object is the type of matter that makes up the object and the way that the matter is arranged in the object. **Figure 5** shows both a physical and a chemical change.

A Change in Composition

Physical changes do not change the composition of a substance. For example, water is made of two hydrogen atoms and one oxygen atom. Whether water is a solid, liquid, or gas, its composition is the same. But chemical changes do alter the composition of a substance. For example, through a process called *electrolysis,* water is broken down into hydrogen and oxygen gases. The composition of water has changed, so you know that a chemical change has taken place.

CONNECTION TO Environmental Science

Acid Rain When fossil fuels are burned, a chemical change takes place. Sulfur from fossil fuels and oxygen from the air combine to produce sulfur dioxide, a gas. When sulfur dioxide enters the atmosphere, it undergoes another chemical change by interacting with water and oxygen. Research this chemical reaction. Make a poster describing the reaction and showing how the final product affects the environment.

ACTIVITY

QUICK LAB

Physical or Chemical Change?

1. Watch as your teacher places a burning **wooden stick** into a **test tube.** Record your observations.
2. Place a mixture of **powdered sulfur** and **iron filings** on a **sheet of paper.** Place a **bar magnet** underneath the paper, and try to separate the iron from the sulfur.
3. Drop an **effervescent tablet** into a **beaker of water.** Record your observations.
4. Identify whether each change is a physical change or a chemical change. Explain your answers.

Reversing Changes

Can physical and chemical changes be reversed? Many physical changes are easily reversed. They do not change the composition of a substance. For example, if an ice cube melts, you could freeze the liquid water to make another ice cube. But composition does change in a chemical change. So, most chemical changes are not easily reversed. Look at **Figure 6.** The chemical changes that happen when a firework explodes would be almost impossible to reverse, even if you collected all of the materials made in the chemical changes.

Figure 6 *This display of fireworks represents many chemical changes happening at the same time.*

SECTION Review

Summary

- Chemical properties describe a substance based on its ability to change into a new substance that has different properties.
- Chemical properties can be observed only when a chemical change might happen.
- Examples of chemical properties are flammability and reactivity.
- New substances form as a result of a chemical change.
- Unlike a chemical change, a physical change does not alter the identity of a substance.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *chemical property* and *chemical change.*

Understanding Key Ideas

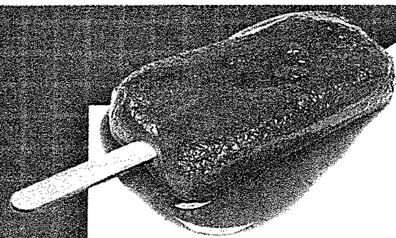
2. Rusting is an example of a
   - **a.** physical property.
   - **b.** physical change.
   - **c.** chemical property.
   - **d.** chemical change.
3. Which of the following is a characteristic property?
   - **a.** density
   - **b.** chemical reactivity
   - **c.** solubility in water
   - **d.** All of the above
4. Write two examples of chemical properties and explain what they are.
5. The Statue of Liberty was originally a copper color. After being exposed to the air, she turned a greenish color. What kind of change happened? Explain your answer.
6. Explain how to tell the difference between a physical and a chemical property.

Math Skills

7. The temperature of an acid solution is 25°C. A strip of magnesium is added, and the temperature rises 2°C each minute for the first 3 min. After another 5 min, the temperature has risen two more degrees. What is the final temperature?

Critical Thinking

8. **Making Comparisons** Describe the difference between physical and chemical changes in terms of what happens to the matter involved in each kind of change.
9. **Applying Concepts** Identify two physical properties and two chemical properties of a bag of microwave popcorn before popping and after.



Chapter Review

USING KEY TERMS

1. Use each of the following terms in a separate sentence: *physical property, chemical property, physical change,* and *chemical change.*

For each pair of terms, explain how the meanings of the terms differ.

2. *mass* and *weight*

3. *inertia* and *mass*

4. *volume* and *density*

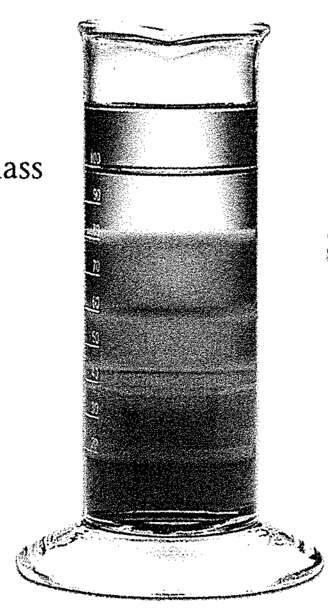
UNDERSTANDING KEY IDEAS

Multiple Choice

5. Which of the following properties is NOT a chemical property?
   - **a.** reactivity with oxygen
   - **b.** malleability
   - **c.** flammability
   - **d.** reactivity with acid

6. The volume of a liquid can be expressed in all of the following units EXCEPT
   - **a.** grams.
   - **b.** liters.
   - **c.** milliliters.
   - **d.** cubic centimeters.

7. The SI unit for the mass of a substance is the
   - **a.** gram.
   - **b.** liter.
   - **c.** milliliter.
   - **d.** kilogram.



8. The best way to measure the volume of an irregularly shaped solid is to
   - **a.** use a ruler to measure the length of each side of the object.
   - **b.** weigh the solid on a balance.
   - **c.** use the water displacement method.
   - **d.** use a spring scale.

9. Which of the following statements about weight is true?
   - **a.** Weight is a measure of the gravitational force on an object.
   - **b.** Weight varies depending on where the object is located in relation to the Earth.
   - **c.** Weight is measured by using a spring scale.
   - **d.** All of the above

10. Which of the following statements does NOT describe a physical property of a piece of chalk?
    - **a.** Chalk is a solid.
    - **b.** Chalk can be broken into pieces.
    - **c.** Chalk is white.
    - **d.** Chalk will bubble in vinegar.

11. Which of the following statements about density is true?
    - **a.** Density is expressed in grams.
    - **b.** Density is mass per unit volume.
    - **c.** Density is expressed in milliliters.
    - **d.** Density is a chemical property.

Short Answer

12. In one or two sentences, explain how the process of measuring the volume of a liquid differs from the process of measuring the volume of a solid.

13 What is the formula for calculating density?

14 List three characteristic properties of matter.

Math Skills

15 What is the volume of a book that has a width of 10 cm, a length that is 2 times the width, and a height that is half the width? Remember to express your answer in cubic units.

16 A jar contains 30 mL of glycerin (whose mass is 37.8 g) and 60 mL of corn syrup (whose mass is 82.8 g). Which liquid is on top? Show your work, and explain your answer.

CRITICAL THINKING

17 **Concept Mapping** Use the following terms to create a concept map: *matter, mass, inertia, volume, milliliters, cubic centimeters, weight,* and *gravity.*

18 **Applying Concepts** Develop a set of questions that would be useful when identifying an unknown substance. The substance may be a liquid, a gas, or a solid.

19 **Analyzing Processes** You are making breakfast for your friend Filbert. When you take the scrambled eggs to the table, he asks, "Would you please poach these eggs instead?" What scientific reason do you give Filbert for not changing his eggs?

20 **Identifying Relationships** You look out your bedroom window and see your new neighbor moving in. Your neighbor bends over to pick up a small cardboard box, but he cannot lift it. What can you conclude about the item(s) in the box? Use the terms *mass* and *inertia* to explain how you came to your conclusion.

21 **Analyzing Ideas** You may sometimes hear on the radio or on TV that astronauts are weightless in space. Explain why this statement is not true.

INTERPRETING GRAPHICS

Use the photograph below to answer the questions that follow.

22 List three physical properties of this aluminum can.

23 When this can was crushed, did it undergo a physical change or a chemical change?

24 How does the density of the metal in the crushed can compare with the density of the metal before the can was crushed?

25 Can you tell what the chemical properties of the can are by looking at the picture? Explain your answer.