SECTION 1

Classifying Matter

Key Ideas

- How can matter be classified?
- Why are carbon and copper classified as elements?
- How are elements related to compounds?
- What is the difference between a pure substance and a mixture?

Key Terms

matter
element
atom
molecule
compound
pure substance
mixture

Why It Matters

By letting a charcoal grill rust outside, you are making a compound. By making a glass of iced tea, you are making a mixture. Understanding matter helps you understand your world.

What do you have in common with this textbook? You are made of matter, and so is this textbook. Your pencil and paper are also made of matter.

What Is Matter?

All of the materials that you can hold or touch are matter. **Matter** is anything that has mass and takes up space. The air that you are breathing is matter even though you cannot see it. Light and sound are not matter. Unlike air, they have no mass or volume.

The study of matter and its changes is what chemistry is about. When chemists study matter, they explore the makeup, properties, changes, and interactions of matter. Chemistry is an important part of your daily life. Many items that you use each day, from soaps to foods and from carbonated drinks to gasoline, are chosen in part for their chemical properties.

One important part of chemistry is classification. The compact discs in **Figure 1** are easy to find because they are classified into groups. All classical music is grouped. Likewise, all pop music is together. Matter can be classified into groups in a similar way. One useful way to classify matter is based on what makes up the matter. **Every sample of matter is either an element, a compound, or a mixture.** For instance, gold is an element, water is a compound, and a vegetable salad is a mixture. You will learn more about each of these types of matter in this section.

matter (MAT uhr) anything that has mass and takes up space

Figure 1 Compact discs are classified by music type. **What is one way to classify matter?**

Elements

When wood gets too hot, it chars—its surface turns black. Its surface breaks down to form carbon, whose properties differ from the properties of wood. The carbon will not decompose further by normal chemical processes. Carbon is an **element,** a substance that cannot be broken down into simpler substances by chemical means.

The smallest unit of an element that keeps the element's chemical properties is an **atom.** › **Each element is made of one kind of atom.** As a result, every known element is unique. The elements carbon and copper are shown in **Figure 2.** Carbon has multiple forms, including diamond and graphite, but each form is made of carbon atoms.

Reading Check **Can elements be broken down into simpler substances?** (See Appendix E for answers to Reading Checks.)

element (EL uh muhnt) a substance that cannot be separated or broken down into simpler substances by chemical means

atom (AT uhm) the smallest unit of an element that maintains the chemical properties of that element

molecule (MAHL i KYOOL) the smallest particle of a substance that has all of the chemical properties of that substance; a molecule is made up of one atom or two or more atoms bonded together

compound (KAHM POWND) a substance made up of atoms of two or more different elements joined by chemical bonds

Figure 2 Every element is made up of a single kind of atom. Both copper and carbon are elements.

Copper wire is made up of copper atoms.

Diamonds are made up of carbon atoms.

Elements are represented by symbols.

Each element is represented by a one- or two-letter symbol that is used worldwide. Symbols for elements are always a single capital letter or a capital letter followed by a lowercase letter. For example, the symbol for carbon is C, and the symbol for aluminum is Al. The periodic table on the inside back cover of this textbook shows all of the elements and the symbols used to represent them. The elements that make up the human body are shown in **Figure 3.** For example, nitrogen, N, makes up 2.4% of the total weight of the human body.

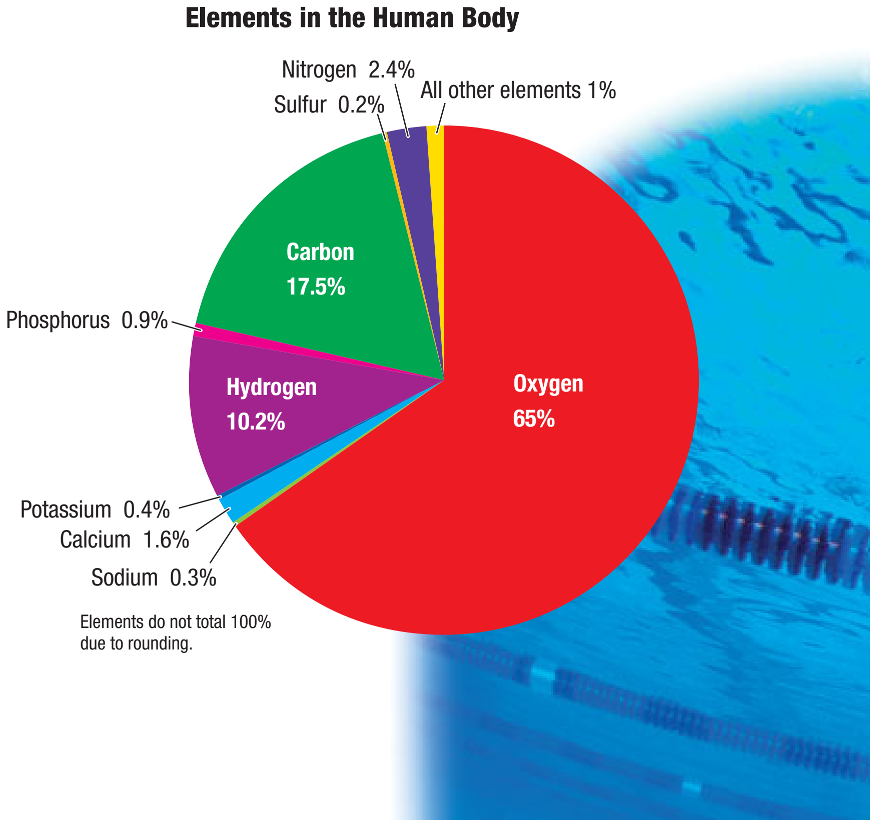


Figure 3 The human body is made up of many elements. **Which element makes up the largest percentage of the total weight of the body?**

Atoms that make up a molecule act as a unit.

Atoms can join to make millions of molecules just as letters of the alphabet combine to form different words. A **molecule** is the smallest unit of a substance that behaves like the substance. The atoms of some elements, such as neon, are found uncombined in nature. Other elements, such as oxygen, form molecules that have more than one atom. **Figure 4** shows some molecules that are made of atoms of the same element.

Compounds

One substance that you are familiar with is water. When oxygen and hydrogen atoms combine to form a molecule of water, the atoms act as a unit. Water is an example of a compound. A **compound** is a substance made up of atoms of different elements. ❯ **Each molecule of a compound contains two or more elements that are chemically combined.**

When elements combine to make a certain compound, they always combine in the same proportions. For example, a water molecule is always made of two hydrogen atoms and one oxygen atom, as **Figure 5** shows. The compound iron (III) oxide, which is often seen as rust, always has two atoms of iron for every three atoms of oxygen.

Compounds have unique properties.

Every compound differs from the elements that it contains. For example, the elements hydrogen, oxygen, and nitrogen are colorless gases. But they combine with carbon to form nylon, a flexible solid. Likewise, the properties of water differ from those of hydrogen and oxygen, which make up water.

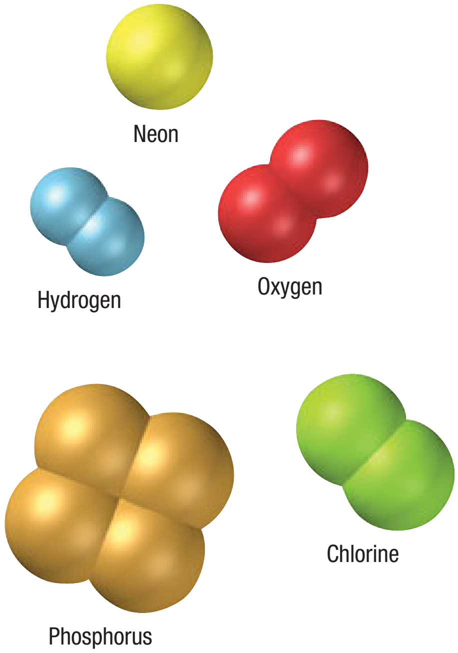


Figure 4 Each of these molecules is made of atoms of the same element. **How many atoms are in one phosphorus molecule?**

Figure 5 Water is an example of a compound. Each water molecule is made up of two hydrogen atoms and one oxygen atom.

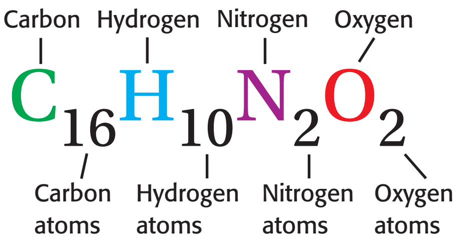


Figure 6 The chemical formula for a molecule of indigo shows that it is made of four elements. **How many atoms are in a molecule of indigo?**

Chemical formulas represent compounds.

Indigo is the dye first used to turn blue jeans blue. The *chemical formula* for a molecule of indigo, $C_{16}H_{10}N_2O_2$, is shown in **Figure 6.** A chemical formula shows how many atoms of each element are in a unit of a substance. The number of atoms of each element is written as a *subscript* after the element's symbol. If only one atom of an element is present, no subscript number is used.

Numbers placed in front of a chemical formula show the number of molecules. So, three molecules of table sugar are written as $3C_{12}H_{22}O_{11}$. Each molecule of sugar contains 12 carbon atoms, 22 hydrogen atoms, and 11 oxygen atoms.

Pure Substances and Mixtures

The word *pure* often means "not mixed with anything." For example, pure grape juice contains the juice of grapes and nothing else. In chemistry, the word *pure* has another meaning. A **pure substance** is matter that has a fixed composition and definite properties.

The composition of grape juice is not fixed. Grape juice is a mixture of pure substances, such as water and sugars. A **mixture** is a combination of substances that are not chemically combined. ❯ **Elements and compounds are pure substances, but mixtures are not.** A mixture can be physically separated into its parts. The parts of a pure substance are chemically combined and cannot be physically separated.

Reading Check **Why are compounds classified as pure substances?**

pure substance (PYOOR SUHB stuhns) a sample of matter, either a single element or a single compound, that has definite chemical and physical properties

mixture (MIKS chuhr) a combination of two or more substances that are not chemically combined

QuickLab

Mystery Mixture

10 min

Procedure

1. Place a **pencil** on a **clear plastic cup.** Use **scissors** to cut a strip of paper (3 cm × 15 cm) from a **coffee filter.** Wrap one end around the pencil. Attach the paper with **tape.**
2. Take the paper out of the cup. Using a **water-soluble, black marker,** make a dot in the center of the strip, 2 cm from the bottom.
3. Pour **water** in the cup to a depth of 1 cm.
4. Lower the paper into the cup. Keep the dot above the water.
5. Remove the paper when the water is 1 cm from the top of the paper. Record your observations.

Analysis

1. What happened as the paper soaked up the water?
2. Which colors make up the black ink?
3. Is the ink-making process a physical change, or is it a chemical change? Explain.

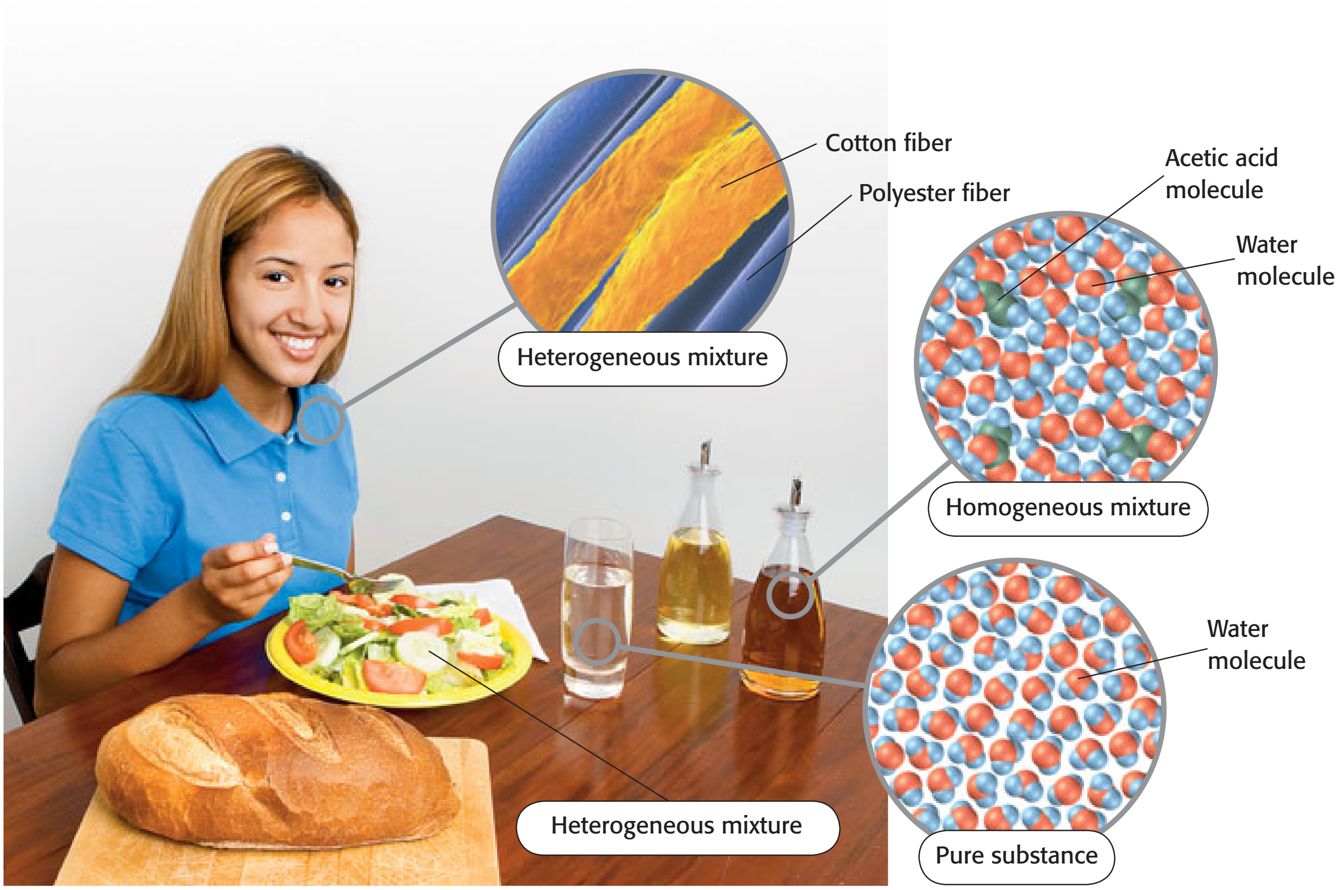


Figure 7 Mixtures are all around you. **What is the difference between the mixtures and the pure substance shown? What is the difference between the two types of mixtures?**

Mixtures are classified by how well the substances mix.

There are several examples of mixtures in **Figure 7.** Mixtures are defined by how well their substances are mixed. The salad is a mixture of lettuce and vegetables. The shirt is a mixture of cotton and polyester fibers. The vinegar in the dressing is a mixture of water and acetic acid. The water is not a mixture. Water is a pure substance because it has a fixed composition and definite properties.

The vegetables in the salad are not evenly distributed. One spoonful may contain tomatoes. Another spoonful may have cucumber slices. A mixture such as a salad is a *heterogeneous mixture*. The substances in a heterogeneous mixture are not evenly distributed. Some heterogeneous mixtures are harder to recognize. The shirt is a heterogeneous mixture because the cotton and polyester fibers are not evenly distributed.

In a *homogeneous mixture*, the components are evenly distributed. The mixture is the same throughout. For example, vinegar is a homogeneous mixture of evenly-distributed water molecules and acetic acid molecules.

Gasoline is a homogeneous mixture of at least 100 liquids. The liquids in gasoline are *miscible,* or able to be mixed. On the other hand, if you shake a mixture of oil and water, the oil and water will not mix well. The water will settle out. Oil and water are *immiscible*. You can see two layers in the mixture.

Integrating **Biology**

Indigo The pure substance indigo is a natural dye made from plants of the genus *Indigofera*, which are in the pea family. Before synthetic dyes were developed, indigo plants were widely grown in Indonesia, in India, and in the Americas. Most species of indigo are shrubs that are 1 to 2 m tall and often have small flowers in spikes or clusters. The dye is made from the leaves and branches of the shrubs. Today, most indigo dye is synthetic rather than natural.

READING TOOLBOX

Finding Examples
Make a list of all of the examples given on this page. Use signal words such as *for example,* but also look for unmarked examples. Next to each example, write the general idea that the example represents.

Gases can mix with liquids.

Carbonated drinks are homogeneous mixtures. They contain sugar, flavorings, and carbon dioxide gas, CO_2, dissolved in water. This example shows that gases can mix with liquids. Liquids that are not carbonated can also contain gases. For example, if you let a glass of cold water sit overnight, bubbles may form inside the glass. The bubbles form when some of the air that was dissolved in the cold water comes out of solution as the water warms up.

Carbonated drinks often have a foam on top. The foam is a gas-liquid mixture. The gas is not dissolved in the liquid but forms tiny bubbles in the liquid. The bubbles join to form bigger bubbles that escape from the foam and cause it to collapse.

Some foams are stable and last for a long time. For example, if you whip egg whites with air, as shown in the photograph on the left in **Figure 8,** you get a foam. When you bake the foam, the liquid egg white dries and hardens, as shown in the photograph on the right. The solid foam is meringue.

Figure 8 The meringue in this pie is a mixture of air and liquid egg white that has been beaten and then heated to form a solid foam.

Section 1 Review

KEY IDEAS

1. **Describe** matter, and explain why light is not classified as matter.
2. **State** the relationship between atoms and elements. Are atoms and elements matter?
3. **Define** *molecule,* and give examples of molecules formed by one element and molecules formed by two elements.
4. **State** the chemical formula of water.
5. **List** the two types of pure substances.

CRITICAL THINKING

6. **Classifying** Classify each of the following as an element or a compound.
   a. sulfur, S_8
   b. methane, CH_4
   c. carbon monoxide, CO
   d. cobalt, Co
7. **Making Comparisons** How are mixtures and pure substances alike? How are they different?
8. **Drawing Conclusions** David says, "Pure honey has nothing else added." Susan says, "The honey is not really pure. It is a mixture of many substances." Who is right? Explain your answer.

SECTION 2

Properties of Matter

Key Ideas

- Why are color, volume, and density classified as physical properties?
- Why are flammability and reactivity classified as chemical properties?

Key Terms

melting point
boiling point
density
reactivity

Why It Matters

Properties determine uses. For instance, the properties of a substance called *aerogel* enable it to trap fast-moving comet particles.

When playing sports, you choose a ball that has the shape and mass suitable for your game. It would be hard to play soccer with a football or to play softball with a bowling ball. The properties of the balls make the balls useful for different activities.

Physical Properties

Shape and mass are examples of *physical properties*. Some other physical properties are color, volume, and texture. The balls in **Figure 1** have different physical properties. **Physical properties are characteristics that can be observed without changing the identity of the substance.** For example, you can determine the color, mass, and shape of a ball without changing the substance that makes up the ball.

Physical properties are often very easy to observe. For instance, you can easily observe that a tennis ball is yellow, round, and fuzzy. Matter can also be described in terms of the absence of a physical property. For example, a physical property of air is that it is colorless.

Physical properties can help identify substances.

Because many physical properties remain constant, you can use your observations or measurements of these properties to identify substances. For example, you recognize your friends by their physical properties, such as height and hair color. At room temperature and under atmospheric pressure, all samples of pure water are colorless and liquid. Pure water is never a powdery green solid. The physical properties of water help you identify water.

Figure 1 The physical properties of these balls make the balls useful in different sports. **How many physical properties can you observe?**

Physical properties can be observed or measured.

You can use your senses to observe some of the basic physical properties of a substance: shape, color, odor, and texture. Another physical property that you can observe is *state*—the physical form of a substance. Solid, liquid, and gas are three common states of matter. For example, water can be in the form of solid ice, liquid water, or gaseous steam.

Other physical properties, such as melting point and boiling point, can be measured. The temperature at which a substance changes from a solid to a liquid is the **melting point.** The temperature at which a liquid changes to a gas is the **boiling point.** A characteristic of any pure substance is that its boiling point and its melting point are constant if the pressure remains the same. At sea level, water boils at 100 °C and freezes at 0 °C. At constant pressure, pure water always has the same boiling point and the same melting point. Regardless of the mass or volume of water, the physical properties of the water are the same. This principle is true for all pure substances.

Other physical properties that can be measured are strength, hardness, and magnetism. The ability to conduct electricity or heat is also a physical property. For instance, copper conducts electricity well, while plastic does not.

Reading Check **Name five examples of physical properties.**

Physical properties help determine uses.

Every day, you use physical properties to recognize substances. Physical properties help you decide whether your socks are clean (odor), whether your books will fit in your backpack (volume), or whether your clothes match (color).

Physical properties are often used to select substances that may be useful. Copper is used in power lines, telephone lines, and electric motors because it conducts electricity well. As **Figure 2** shows, aluminum is used in foil because it is lightweight yet durable and flexible. Car frames are made of steel, which is a strong solid that provides structure. Tires are made of a flexible solid that cushions your ride. Antifreeze is used in car radiators because it remains a liquid at temperatures that would freeze or boil water.

Can you think of other physical properties that help us determine how we can use a substance? Some substances have the ability to conduct heat, while others do not. Plastic-foam cups do not conduct heat well, so they are often used for holding hot drinks. What would happen if you poured hot tea into a metal cup?

READING TOOLBOX

Finding Examples
As you read this section, find examples for each property that is discussed. Don't forget to use signal words as clues. Make a table of properties and examples.

melting point (MELT ing POYNT) the temperature and pressure at which a solid becomes a liquid

boiling point (BOYL ing POYNT) the temperature and pressure at which a liquid becomes a gas

Academic Vocabulary

durable (DUR uh buhl) able to withstand wear or damage

flexible (FLEK suh buhl) capable of bending easily without breaking

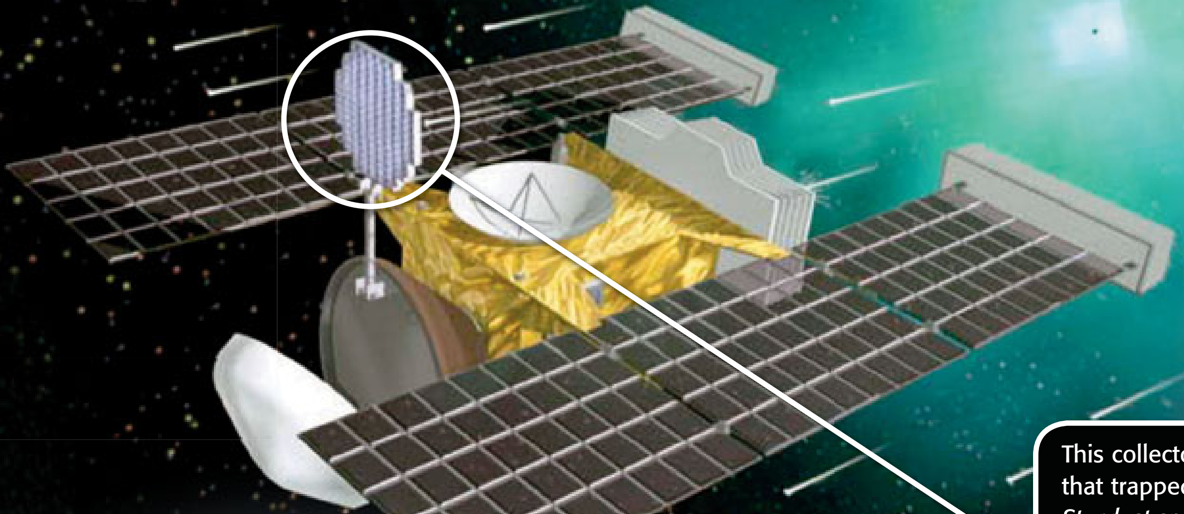
Figure 2 Aluminum is light, strong, and durable, which makes it ideal for use in foil.

Why It **Matters**

Aerogel

Aerogel, nicknamed "solid blue smoke," is a substance with unique physical properties. For instance, aerogel has the lowest density of any known solid. Air makes up 99.8% of one form of aerogel. Glass is 1,000 times as dense as aerogel! NASA's *Stardust* mission, shown below, used aerogel to trap thousands of tiny, fast-moving comet particles. Aerogel's unique properties enabled it to capture the particles without damaging or vaporizing them.

WEIRD SCIENCE



This collector contains the aerogel that trapped comet dust as the *Stardust* spacecraft passed through comet Wild 2. The spacecraft returned successfully in January of 2006. Scientists all over the world are studying the particles to learn more about comets.

Aerogel can withstand very high temperatures. These crayons are not melting because aerogel protects them from the flame below. Aerogel is also very strong. It can support 4,000 times its own weight. These properties make aerogel ideal for space missions.

YOUR TURN

UNDERSTANDING CONCEPTS

1. What are some physical properties of aerogel?

CRITICAL THINKING

2. NASA used aerogel to protect the *Sojourner* rover from the cold environment on Mars. What property makes aerogel useful for this purpose?

SCILINKS.
www.scilinks.org
Topic: Aerogel
Code: **HK81695**

density (DEN suh tee) the ratio of the mass of a substance to the volume of the substance

SCILINKS.
www.scilinks.org
Topic: Density
Code: **HK80388**

Density is a physical property.

Another physical property is *density*. **Density** is a measurement of how much matter is contained in a certain volume of a substance. The density of an object is calculated by dividing the object's mass by the object's volume.

Density equation $D = \frac{m}{V}$ $\quad$ $density = \frac{mass}{volume}$

The density of a liquid or a solid is usually expressed in grams per cubic centimeter (g/cm^3). For example, 10.0 cm^3 of water has a mass of 10.0 g. Thus, the water's density is 10.0 g for every 10.0 cm^3, or 1.00 g/cm^3. A cubic centimeter has the same volume as a milliliter (mL).

Reading Check **What is the density of water in grams per milliliter?**

Math Skills Density

If 10.0 cm^3 of ice has a mass of 9.17 g, what is the density of ice?

Identify List the given and the unknown values.	**Given:** *mass,* $m = 9.17$ g; *volume,* $V = 10.0\ cm^3$ **Unknown:** *density,* $D = ?\ g/cm^3$
Plan Write the equation for density.	$density = \frac{mass}{volume}$ $D = \frac{m}{V}$
Solve Insert the known values into the equation, and solve.	$D = \frac{9.17\ g}{10.0\ cm^3}$ $D = 0.917\ g/cm^3$

Practice

1. A piece of tin has a mass of 16.52 g and a volume of 2.26 cm^3. What is the density of tin?
2. A man has a 50.0 cm^3 bottle completely filled with 163 g of a slimy, green liquid. What is the density of the liquid?
3. A piece of metal has a density of 11.3 g/cm^3 and a volume of 6.7 cm^3. What is the mass of this piece of metal?

For more practice, visit **go.hrw.com** and enter keyword **HK8MP.**

Practice Hint

› Problem 3: You can solve for mass by multiplying both sides of the density equation by volume.

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

$$DV = \frac{m\cancel{V}}{\cancel{V}}$$

$$m = DV$$

QuickLab

Density of Water

20 min

Procedure

1. Find the mass of an empty **100 mL graduated cylinder.**
2. Pour 10 mL of **water** from a **250 mL beaker** into the graduated cylinder. Use a **balance** to find the mass of the graduated cylinder that contains the water.
3. Repeat Step 2 for several different volumes of water.
4. Use **graph paper** or a **graphing calculator** to plot volume (on the *x*-axis) versus mass (on the *y*-axis).

Analysis

1. Estimate the mass of 55 mL of water and 85 mL of water.
2. Predict the volume of 25 g of water and 75 g of water.
3. Use your graph to determine the density of water.

Density is different from weight.

A substance that has a low density is "light" in comparison with something else of the same volume. The balloons in **Figure 3** float because the denser air sinks around them. A substance that has a high density is "heavy" in comparison with another object of the same volume. A stone sinks to the bottom of a pond because the stone is denser than the water.

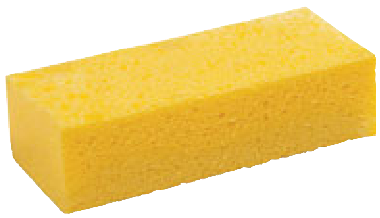
The brick and sponge shown in **Figure 4** have similar volumes, but the brick is more massive than the sponge. Because the brick has more mass per unit of volume than the sponge does, the brick is denser. If you held the brick in one hand and the sponge in the other hand, you would know instantly that the brick is denser than the sponge.

Although the denser brick feels heavier than the sponge, weight and density are different. In the example of a brick and sponge, both objects have about the same volume. But compare two objects that have different volumes. Two pounds of feathers are heavier than one pound of steel. But the feathers are less dense than the steel, so two pounds of feathers have a greater volume than one pound of steel does.

Figure 3 Helium-filled balloons float because helium is less dense than air. Hot-air balloons rise for a similar reason. **Which is less dense: hot air or cool air?**

More mass

Denser



Less mass

Less dense

Figure 4 This brick is denser than this sponge because the brick has more matter in a similar volume. **If a brick and a sponge have equal masses, which has less volume?**

Chemical Properties

Some elements react very easily with other elements. For example, because magnesium is very reactive, it is used to make emergency flares. Reactive elements are usually found as compounds in nature. Other elements, such as gold, are much less reactive. These elements are often found uncombined. Light bulbs are filled with argon gas because it is not very reactive.

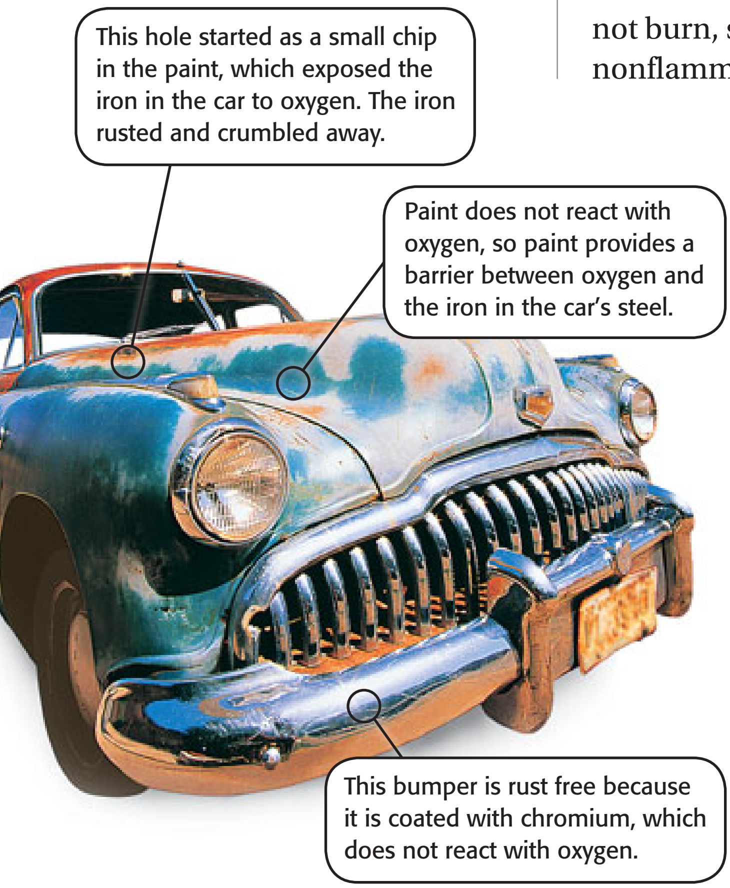
reactivity (REE ak TIV uh tee) the capacity of a substance to combine chemically with another substance

These properties are examples of *chemical properties.* ❯ **A chemical property describes how a substance changes into a new substance, either by combining with other elements or by breaking apart into new substances.** Chemical properties are related to the specific elements that make up substances. Chemical properties are generally not as easy to observe as physical properties.

Flammability is a chemical property.

One chemical property is *flammability*—the ability to burn. For example, wood can be burned to form new substances that have new properties. So, one chemical property of wood is flammability. Even when wood is not burning, it is flammable. A substance always has its chemical properties, even when you cannot observe them. A substance that does not burn, such as gold, has the chemical property of nonflammability.

Figure 5 One chemical property is reactivity. **Which reacts more easily with oxygen: iron, paint, or chromium?**



Reactivity is a chemical property.

Another chemical property is the reactivity of elements or compounds with oxygen, water, or other substances. **Reactivity** is the capacity of a substance to combine with another substance. For example, although iron has many useful properties, its reactivity with oxygen is one property that can cause problems. When exposed to oxygen, iron rusts. You can see rust on the old car shown in **Figure 5.** Why does rust occur? The steel parts of a car rust when iron atoms in the steel react with oxygen in air to form iron(III) oxide. The painted and chromium parts of the car do not rust because they do not react with oxygen. In other words, the elements in steel, paint, and chrome have different chemical properties.

Reading Check **Name two chemical properties.**

Why It **Matters**

Identifying Mystery Substances

FORENSICS

Forensic scientists use physical and chemical properties to identify substances, such as paint, glass, or fibers. For instance, paint chips from an accident can be analyzed to learn about the car from which the paint came. Although this method does not always provide conclusive evidence, it can be used to support further investigation.

1 The first step is to collect the paint chips. This forensic investigator is using a scraping tool to collect paint from a car.

2 This scientist is studying a sample under a microscope to look for small traces of paint left by another car.

3 The next step is to study the collected sample's physical and chemical properties. Physical properties include color, layer sequence, and layer thickness. Chemical properties include pigments and additives.

4 The physical and chemical properties can then be compared with a database of paint properties for different makes and models of automobiles. The investigators can use this information to determine from what kind of car the paint sample most likely came.

YOUR TURN

UNDERSTANDING CONCEPTS

1. Why is layer thickness a physical property?

CRITICAL THINKING

2. What is one situation in which the database of automobile paint would not provide information about the unknown car?

QuickLab 10 min

Reactivity

1. Measure 4 g each of **compounds A** and **B.** Place them in separate **clear plastic cups.**
2. Observe the color and texture of each compound. Record your observations.
3. Add 5 mL of **vinegar** to each cup. Record your observations.
4. Baking soda reacts with vinegar, but powdered sugar does not. Which of these two substances is compound A, and which is compound B?

Physical and chemical properties are different.

It is important to remember the differences between physical and chemical properties. You can observe physical properties without changing the identity of the substance. But you can observe chemical properties only in situations in which the identity of the substance changes.

Figure 6 summarizes the physical and chemical properties of a few common substances. Some substances have similar physical properties but different chemical properties. Other substances have similar chemical properties but different physical properties. For example, wood and rubbing alcohol both have the chemical property of flammability, but they have different physical properties.

Figure 6 Comparison of Physical and Chemical Properties

Substance	Wood	Iron	Red dye
			
Physical property	has a grainy texture	bends without breaking	has red color
Chemical property	is flammable	reacts with oxygen to form rust	reacts with bleach; loses color

Section 2 Review

KEY IDEAS

1. **List** two physical properties and two chemical properties.
2. **Identify** the following as physical properties or chemical properties.
   - **a.** reacts with water
   - **b.** is red
   - **c.** is shiny and silvery
   - **d.** melts easily
   - **e.** boils at 100 °C
   - **f.** is nonflammable
   - **g.** has a low density
   - **h.** tarnishes in moist air

CRITICAL THINKING

3. **Applying Concepts** Describe several uses for plastic, and explain why plastic is a good choice for these purposes.
4. **Making Inferences** Suppose that you need to build a raft. Write a paragraph describing the physical and chemical properties of the raft that would be important to ensure your safety.

Math Skills

5. Calculate the density of a rock that has a mass of 454 g and a volume of 100.0 cm^3.
6. Calculate the density of a substance in a sealed 2,500 cm^3 flask that is full to capacity with 0.36 g of a substance.
7. A sample of copper has a volume of 23.4 cm^3. If the density of copper is 8.9 g/cm^3, what is the copper's mass?

SECTION 3

Changes of Matter

Key Ideas

- Why is a getting a haircut an example of a physical change?
- Why is baking bread an example of a chemical change?
- How can mixtures and compounds be broken down?

Key Terms

physical change
chemical change

Why It Matters

The process of making glass—for practical applications or as art—involves both physical and chemical changes.

Leaves change color in the fall, an ice cube melts in your glass, and bread dough turns into bread when it bakes in the oven. Such changes occur in matter as a result of physical or chemical changes.

Physical Changes

If you break a piece of chalk, you change its physical properties of size and shape. But no matter how many times you break the chalk, its chemical properties remain unchanged. The chalk is still chalk, and each piece of chalk would produce bubbles if you placed it in vinegar. Breaking chalk is an example of a **physical change. ❯ A physical change affects one or more physical properties of a substance without changing the identity of the substance.**

Figure 1 shows several examples of physical changes. Some other examples of physical changes are dissolving sugar in water, sanding a piece of wood, and mixing oil and vinegar.

physical change (FIZ i kuhl CHAYNJ) a change of matter from one form to another without a change in chemical properties

Figure 1 Examples of Physical Changes

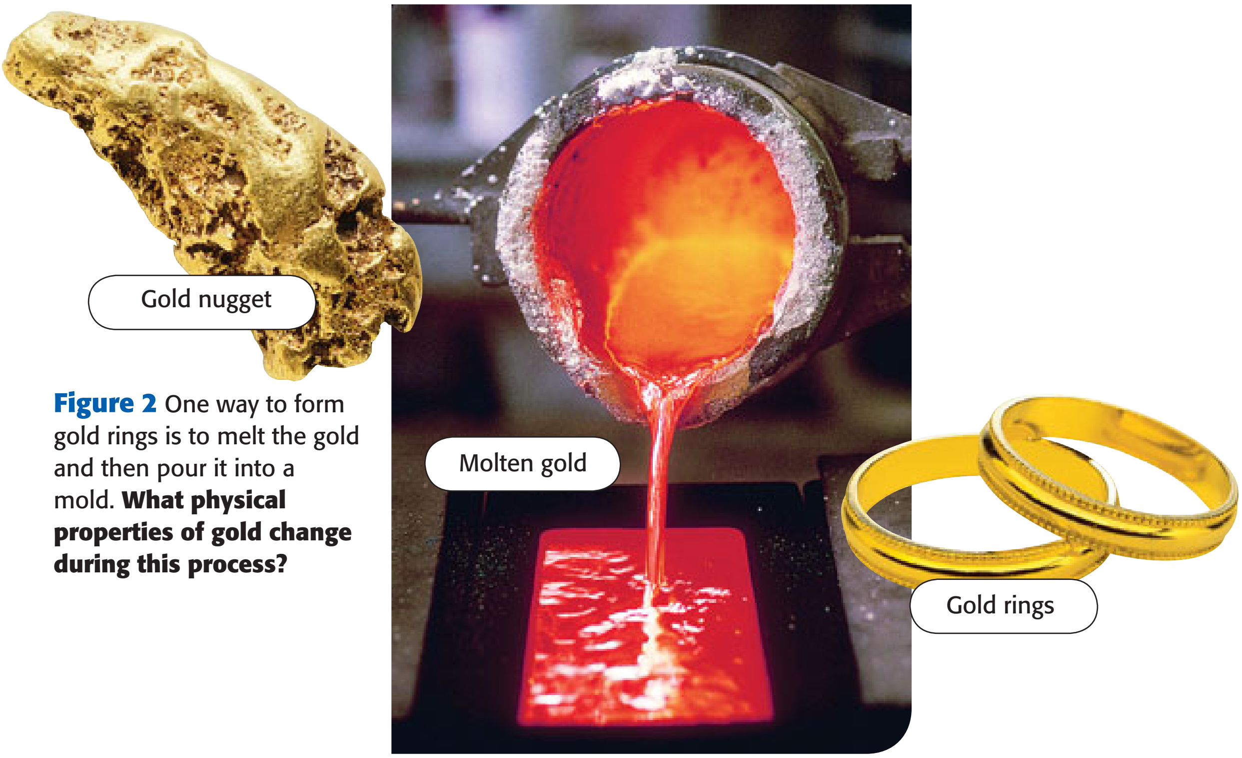


Figure 2 One way to form gold rings is to melt the gold and then pour it into a mold. **What physical properties of gold change during this process?**

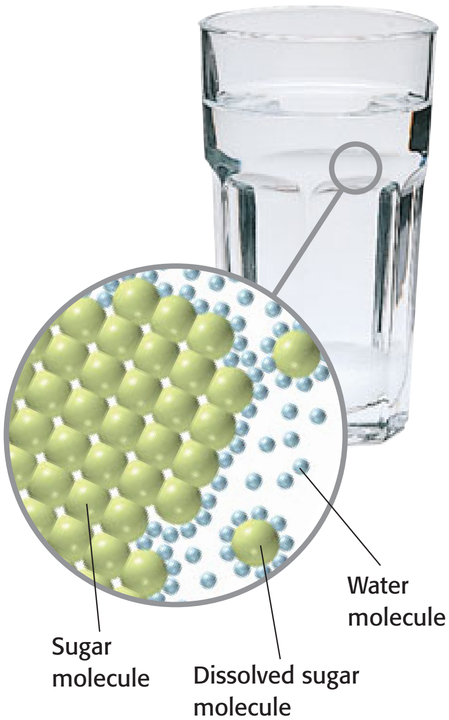


Figure 3 When sugar dissolves in water, the water molecules attract the sugar molecules and pull them apart. As a result, the sugar molecules spread out in the water.

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Physical changes do not change a substance's identity.

Melting a gold nugget to form a gold ring involves several physical changes, as **Figure 2** shows. The gold changes from solid to liquid and then back to solid. The shape of the gold also changes. The gold nugget becomes a ring of gold. But these physical changes do not change all of the properties of the gold. For example, the gold's color, melting point, and density do not change.

During a physical change, energy is absorbed or released. After a physical change, a substance may look different, but the arrangement of atoms that make up the substance is not changed. A gold nugget, molten gold, and gold rings are all made of gold atoms.

Dissolving is a physical change.

When you stir sugar into water, the sugar dissolves and seems to disappear. But the sugar is still there. You can taste the sweetness when you drink the water. What happened to the sugar?

Figure 3 shows sugar molecules dissolving in water. (The sugar and water molecules are represented as spheres to simplify the diagram.) When sugar dissolves, the sugar molecules become spread out between the water molecules. The molecules of the sugar do not change. So, dissolving is an example of a physical change.

Chemical Changes

Some materials are useful because of their ability to change and combine to form new substances. For example, the compounds in gasoline burn in the presence of oxygen to form carbon dioxide and water. The burning of the compounds is a **chemical change.** **A chemical change happens when one or more substances are changed into entirely new substances that have different properties.** The chemical properties of a substance describe which chemical changes can happen. You can learn about chemical properties by observing chemical changes.

chemical change (KEM i kuhl CHAYNJ) a change that occurs when one or more substances change into entirely new substances with different properties

Reading Check **What is the difference between a physical change and a chemical change?**

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Topic: Physical/Chemical Changes
Code: HK81145

Chemical changes happen everywhere.

You see chemical changes happening more often than you may think. When a battery dies, the chemicals inside the battery have changed, so the battery can no longer supply energy. The oxygen that you inhale when you breathe is used in a series of chemical reactions in your body. After the oxygen reacts with molecules containing carbon, the oxygen is then exhaled as part of the compound carbon dioxide. Chemical changes occur when fruits and vegetables ripen and when the food you eat is digested. **Figure 4** shows some other examples of chemical changes.

Figure 4 **Examples of Chemical Changes**

Chemical reactions produce pigments that give leaves their colors. In the fall, green leaves change colors as different reactions take place.

When effervescent tablets are added to water, the citric acid and baking soda in them react to produce carbon dioxide, which forms bubbles.

The shiny, orange-brown copper of the Statue of Liberty has reacted with carbon dioxide and water to form green copper compounds.

Figure 5 These ingredients are combined and baked to make French bread. **What evidence shows that chemical changes occurred?**

Chemical changes form new substances.

When you bake French bread, you combine the ingredients shown in **Figure 5:** water, flour, yeast, and salt. Each ingredient has its own set of properties. When you mix the ingredients and heat them in an oven, the heat of the oven and the interaction of the ingredients cause chemical changes. These changes result in bread, whose properties differ from the properties of the ingredients. This is an example of how new substances are formed by chemical changes.

Academic Vocabulary

interaction (IN tuhr AK shuhn) the action or influence between things

Chemical changes can be detected.

When a chemical change takes place, clues often suggest that a chemical change has happened. A change in odor or color is a good clue that a substance is changing chemically. When food burns, you can often smell the gases given off by the chemical changes. When paint fades, you can observe the effects of chemical changes in the paint. Chemical changes often cause color changes, fizzing or foaming, or the production of sound, heat, light, or odor.

Figure 6 shows table sugar being heated on a dessert to form a thin caramel layer. How do you know a chemical change is taking place? The sugar has changed color, bubbles are forming, and a caramel smell is filling the air.

Figure 6 Table sugar is a compound made of carbon, hydrogen, and oxygen. When table sugar is heated, it caramelizes.

Chemical changes cannot be reversed by physical changes.

Because new substances are formed in a chemical change, a chemical change cannot be reversed by physical changes. Most of the chemical changes that you observe in your daily life, such as bread baking, milk turning sour, or iron rusting, are impossible to reverse. Imagine trying to unbake a loaf of bread! However, under the right conditions, some chemical changes can be reversed by other chemical changes. For example, the water that forms in a space shuttle's rockets can be split into hydrogen and oxygen by using an electric current to start a reaction.

Breaking Down Mixtures and Compounds

You know that a mixture is a combination of substances that are not chemically combined. A compound, on the other hand, is made up of atoms that are chemically combined. As a result of this difference, mixtures and compounds must be separated in different ways. ❯ **Mixtures can be separated by physical changes, but compounds must be broken down by chemical changes.**

Reading Check Why must mixtures and compounds be separated in different ways?

Mixtures can be physically separated.

Because mixtures are not chemically combined, each part of a mixture has the same chemical makeup that it had before the mixture was formed. Each substance keeps its identity. Thus, mixtures can be separated by physical means.

In some mixtures, such as a pizza, you can see the components. You can remove the mushrooms on a pizza. The removal results in a physical change. Not all mixtures are this easy to separate. For example, you cannot pick salt out of saltwater. But you can separate saltwater into its parts by heating it. When the water evaporates, the salt remains.

If components of a mixture have different boiling points, you can heat the mixture in a distillation device. The component that boils and evaporates first separates from the mixture. Another technique for separating mixtures is to use a centrifuge, which spins a mixture rapidly until the components separate. **Figure 7** shows blood separated by a centrifuge.

Figure 7 You can see layers in this blood sample because it has been separated into its components by the centrifuge. **Is blood a mixture or a compound?**

InquiryLab Can You Separate a Mixture?

30 min

Procedure

1. Study the **sample mixture** provided by your teacher.
2. Design an experiment in which the following materials are used to separate the components of the mixture: **distilled water, filter funnel, filter paper, magnet, paper towels, clear plastic cup,** and **plastic spoon.** Consider physical properties such as density, magnetism, and the ability to dissolve.

Analysis

1. What properties did you observe in each of the components of the mixture?
2. How did these properties help you to separate the components of the sample?
3. Did any of the components share similar properties?
4. Based on your observations, what items do you think made up the mixture?

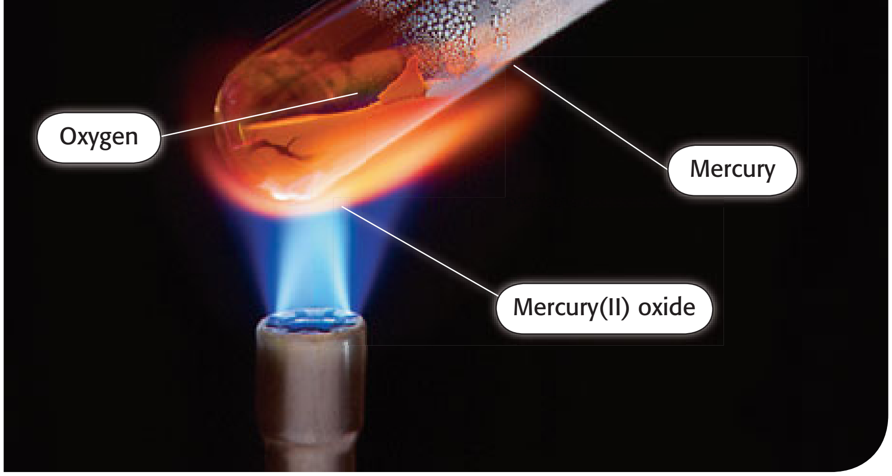

Figure 8 Heating the compound mercury(II) oxide breaks it down into the elements mercury and oxygen. **Is this change a physical change or a chemical change?**

Some compounds can be broken down through chemical changes.

Some compounds can be broken down into elements through chemical changes. For instance, when the compound mercury(II) oxide is heated, it breaks down into the elements mercury and oxygen. This process is shown in **Figure 8.** Electric currents can be used to separate some compounds. For example, if a current is passed through melted table salt, which is a compound, the elements sodium and chlorine are produced.

Other compounds undergo chemical changes to form simpler compounds. When you open a bottle of soda, compounds in the soda break down into carbon dioxide and water. The carbon dioxide escapes as bubbles. The escaping carbon dioxide is the reason that a soda bubbles when you open it. Through additional chemical changes, the carbon dioxide and water can be further broken down into the elements carbon, oxygen, and hydrogen.

READING TOOLBOX

Two-Column Notes
Create two-column notes to review the Key Ideas for this section. Put the Key Ideas in the left column, and add details and examples in your own words in the right column.

Section 3 Review

KEY IDEAS

1. **Define** *physical change* and *chemical change,* and give examples of each type of change.
2. **Explain** why changes of state are physical changes.
3. **Describe** how you would separate the components of a mixture of sugar and sand. Would your methods result in physical or chemical changes?
4. **Explain** why physical changes can easily be reversed but why chemical changes cannot.
5. **Identify** two ways to break down a compound into simpler substances.
6. **List** three clues that indicate a chemical change.

CRITICAL THINKING

7. **Classifying** Classify each of the following as a chemical change or a physical change.
   - **a.** sugar being added to lemonade
   - **b.** plants using carbon dioxide and water to form oxygen and sugar
   - **c.** water boiling
   - **d.** an egg frying
   - **e.** rust forming on metal
   - **f.** fruit rotting
   - **g.** salt being removed from water by evaporation
8. **Making Inferences** Describe the difference between physical and chemical changes in terms of what happens to the molecules.

Why It **Matters**

REAL WORLD

How Is Glass Made?

People have been making glass for thousands of years. The raw materials of sand, limestone, and soda ash are heated and turned into glass through chemical changes. Several physical changes, including changes in state, shape, and size, also occur. There are different ways to shape the glass once it has been made. One method, called *glass blowing,* is illustrated below.

1 Glassmakers often purchase the raw ingredients—sand, limestone, and soda ash—mixed together in a form called *batch*. When the batch is heated to about 1,500 °C, the mixture becomes transparent and flows like honey.

2 A glass blower dips a hollow iron blowpipe into the hot mixture and picks up a gob of molten glass. The blower occasionally reheats the glass to keep it soft.

3 By turning the sticky glob and blowing into the tube, the glass blower creates a hollow bulb that can be pulled, twisted, and blown into different shapes. When the finished shape is broken from the tube, a work of art has been created.

YOUR TURN

UNDERSTANDING CONCEPTS

1. After the molten glass has been shaped, it cools and solidifies. Is this a physical change or a chemical change?

WRITING IN SCIENCE

2. Research another method of shaping glass, such as pressing, drawing, or casting. Write a paragraph describing this method.

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Topic: Glass
Code: **HK80678**

Converting Units

Science Skills

Technology

Math

Scientific Methods

Graphing

Problem

Density can be expressed in grams per cubic centimeter (g/cm^3). The density of lead is 11.3 g/cm^3. What is the density of lead in grams per cubic millimeter (g/mm^3)?

Solution

Identify

List the given and unknown values.

Given:

$density,\ d = 11.3\ \mathrm{g/cm^3}$

Unknown:

$density,\ d = ?\ \mathrm{g/mm^3}$

Plan

a. Determine the relationship between units. Because cm is cubed, the conversion value must also be cubed.

a. $1\ \mathrm{cm} = 10\ \mathrm{mm}$

$1\ \mathrm{cm^3} = (10\ \mathrm{mm})^3 = 1{,}000\ \mathrm{mm^3}$

b. Write the equation for the conversion. Use the units as a guide. If the units don't cancel properly, you may have the conversion equation backwards.

b. $\text{density in g/mm}^3 = \text{density in } \frac{\mathrm{g}}{\cancel{\mathrm{cm^3}}} \times \frac{1\ \cancel{\mathrm{cm^3}}}{1{,}000\ \mathrm{mm^3}}$

Solve

Insert the known values into the equation, and solve.

$$\text{density in g/mm}^3 = \frac{11.3\ \mathrm{g}}{\cancel{\mathrm{cm^3}}} \times \frac{1\ \cancel{\mathrm{cm^3}}}{1{,}000\ \mathrm{mm^3}}$$

$$d = 0.0113\ \mathrm{g/mm^3}$$

Practice

Use the table to answer the following questions.

1. Find the density of dry air in the following units:
   a. grams per cubic millimeter (g/mm^3)
   b. grams per cubic meter (g/m^3)
2. What is the density of water in grams per cubic millimeter?
3. Find the density of helium in grams per cubic meter.
4. Will the density of gasoline in grams per cubic meter be greater than or less than the value given in the table? To see if you are correct, convert the value given in the table to grams per cubic meter.
5. What is the density of iron in grams per cubic meter?

Substance	Density (g/cm^3)
Air (dry)	0.00129
Brick (common)	1.9
Gasoline	0.7
Helium	0.00018
Ice	0.92
Iron	7.86
Lead	11.3
Nitrogen	0.00125
Steel	7.8
Water	1.00