

2

Matter and Change

INSIDE:

- 2.1 Properties of Matter
- 2.2 Mixtures
- 2.3 Elements and Compounds
- 2.4 Chemical Reactions

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As a grilled cheese sandwich cooks, physical and chemical changes are taking place. Melting cheese is a physical change. Toasting bread is a chemical change.

BIG IDEA

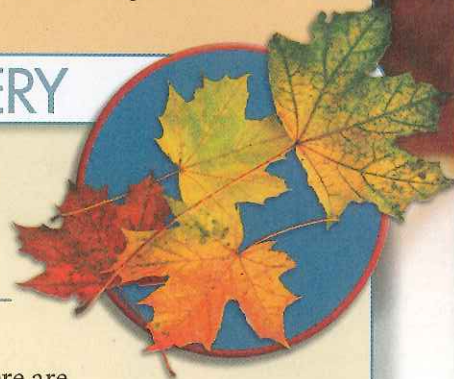
CHEMISTRY AS THE CENTRAL SCIENCE

Essential Questions:

1. *What properties are used to describe matter?*
2. *How can matter change its form?*

CHEMYSTERY

Which One Is Not Like the Others?



In Yellowstone National Park, there are more than 300 geysers. If you are able to witness a geyser erupting, you will see water and steam shooting out of the ground.

In Glacier National Park, the bottoms of glaciers go through melting and freezing cycles. These cycles produce valleys that are scoured into a U-shape and are flanked by steep sides of earth.

In Acadia National Park, the leaves on the deciduous trees change color each fall. The leaves go from green to red, orange, or yellow.

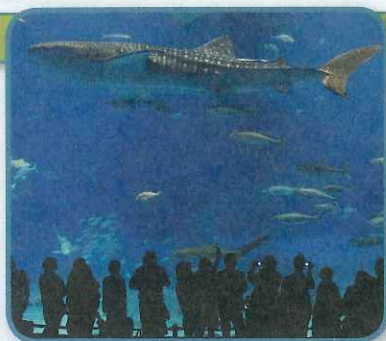
All three of these sights are amazing to see. They all result from changes. Are they physical or chemical changes? One of them is not like the others. But which one is different, and why?

► Connect to the **BIG IDEA** As you read about matter, think about how matter is altered by physical and chemical changes.

NATIONAL SCIENCE EDUCATION STANDARDS

A-1, B-2, B-3, E-2, G-3

2.1 Properties of Matter



CHEMISTRY & YOU

Q: *Why are windows made of glass?* When you think of a window, you probably think of something that you can look through. Most windows are made of glass and are transparent, meaning you can see through them. If you found a piece of broken glass on the ground, you would probably recognize it as glass. It is hard, yet easy to shatter, and it is heat resistant. In this lesson, you will learn how properties can be used to classify and identify matter.

Key Questions

🔑 *Why do all samples of a substance have the same intensive properties?*

🔑 *What are three states of matter?*

🔑 *How can physical changes be classified?*

Vocabulary

- mass
- volume
- extensive property
- intensive property
- substance
- physical property
- solid
- liquid
- gas
- vapor
- physical change

Describing Matter

🔑 *Why do all samples of a substance have the same intensive properties?*

Understanding matter begins with observation, and what you observe when you look at a particular sample of matter is its properties. Is a solid shiny or dull? Does a liquid flow quickly or slowly? Is a gas odorless, or does it have a smell? Properties used to describe matter can be classified as extensive or intensive properties.

Extensive Properties Recall that matter is anything that has mass and takes up space. The **mass** of an object is a measure of the amount of matter the object contains. The mass of the basketball in Figure 2.1 is greater than the mass of the golf ball. There is also a difference in the volume of the balls. The **volume** of an object is a measure of the space occupied by the object. The volume of the basketball is greater than the volume of the golf ball. Mass and volume are both examples of extensive properties. An **extensive property** is a property that depends on the amount of matter in a sample.

Intensive Properties Basketballs may appear to be all the same. But, there are properties to consider when selecting a basketball besides mass and volume. The outer covering may be made of leather, rubber, or a synthetic composite. Each of these materials has different properties which make the basketballs suitable for different playing situations. For example, leather balls are suitable for indoor play but not outdoor play. Leather balls absorb water and dirt more than rubber balls. Absorbancy is an example of an intensive property. An **intensive property** is a property that depends on the type of matter in a sample, not the amount of matter.

Figure 2.1 Extensive Properties
Golf balls and basketballs have different masses and different volumes.



Identifying a Substance Each object in Figure 2.2 has a different chemical makeup, or composition. The soda can is mainly aluminum. The watering can is mainly copper. Matter that has a uniform and definite composition is called a **substance**. Aluminum and copper are examples of substances, which are also referred to as *pure substances*. **Key** Every sample of a given substance has identical intensive properties because every sample has the same composition.

Aluminum and copper have some properties in common, but there are differences besides their distinctive colors. Aluminum is highly reflective and is often used in silver paints. Pure copper can scratch the surface of pure aluminum because copper is harder than aluminum. Copper is better than aluminum as a conductor of heat or electric current. Copper and aluminum are both malleable, which means they can be hammered into sheets without breaking. Hardness, color, conductivity, and malleability are examples of physical properties. A **physical property** is a quality or condition of a substance that can be observed or measured without changing the substance's composition.

Table 2.1 lists physical properties for some substances. The states of the substances are given at room temperature. (Although scientists use room temperature to refer to a range of temperatures, in this book it will be used to refer to a specific temperature, 20°C.) Physical properties can help chemists identify substances. For example, a colorless substance that was found to boil at 100°C and melt at 0°C would likely be water. A colorless substance that boiled at 78°C and melted at -117°C would definitely not be water. Based on Table 2.1, it would likely be ethanol.



Figure 2.2 Aluminum and Copper

This soda can is made almost entirely of a thin sheet of aluminum. The watering can is made of copper, which has been hammered to give its textured appearance.

Analyze Data Which of the properties listed in Table 2.1 could not be used to distinguish copper from aluminum?

CHEMISTRY & YOU

Q: Glass is often used to make windows, while copper is often used in electrical wires. What properties of glass make it a desirable material to use for windows?

Interpret Data

Physical Properties of Some Substances

Substance	State	Color	Melting point (°C)	Boiling point (°C)
Neon	Gas	Colorless	-249	-246
Oxygen	Gas	Colorless	-218	-183
Chlorine	Gas	Greenish-yellow	-101	-34
Ethanol	Liquid	Colorless	-117	78
Mercury	Liquid	Silvery-white	-39	357
Bromine	Liquid	Reddish-brown	-7	59
Water	Liquid	Colorless	0	100
Sulfur	Solid	Yellow	115	445
Aluminum	Solid	Silver	660	2519
Sodium chloride	Solid	White	801	1413
Gold	Solid	Yellow	1064	2856
Copper	Solid	Reddish-yellow	1084	2562

Table 2.1 A substance can be described and identified by its physical properties.

a. Identify Which property can most easily distinguish chlorine from the other gases?

b. Identify A colorless liquid boils at 40°C. Is the substance water? Why or why not?

c. Calculate Which of the liquid substances has the highest melting point? The lowest boiling point?

d. Draw Conclusions Which of the properties would be the most helpful in identifying an unknown substance?

States of Matter

🔑 What are three states of matter?

Depending on the circumstances, you use three different words to refer to water—water, ice, and steam. Water, which is a common substance, exists in three different physical states. So can most other substances. 🔑 **Three states of matter are solid, liquid, and gas.** Certain characteristics that can distinguish these three states of matter are summarized in Figure 2.3.

Solids A **solid** is a form of matter that has a definite shape and volume. The shape of a solid doesn't depend on the shape of its container. The particles in a solid are packed tightly together, often in an orderly arrangement, as shown in Figure 2.3a. As a result, solids are almost incompressible; that is, it is difficult to squeeze a solid into a smaller volume. In addition, solids expand only slightly when heated.

Liquids Look at Figure 2.3b. The particles in a liquid are in close contact with one another, but the arrangement of particles in a liquid is not rigid or orderly. Because the particles in a liquid are free to flow from one location to another, a liquid takes the shape of the container in which it is placed. However, the volume of the liquid doesn't change as its shape changes. The volume of a liquid is fixed or constant. Thus, a **liquid** is a form of matter that has an indefinite shape, flows, yet has a fixed volume. Liquids are almost incompressible, but they tend to expand slightly when heated.

Figure 2.3

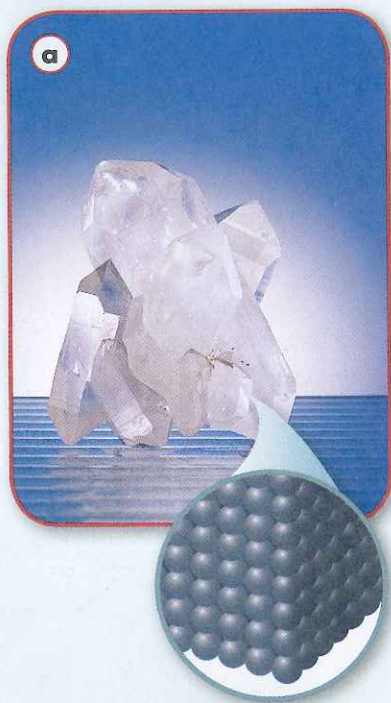
The arrangement of particles is different in solids, liquids, and gases.

Relate Cause and Effect Use the arrangements of their particles to explain the general shape and volume of solids and gases.

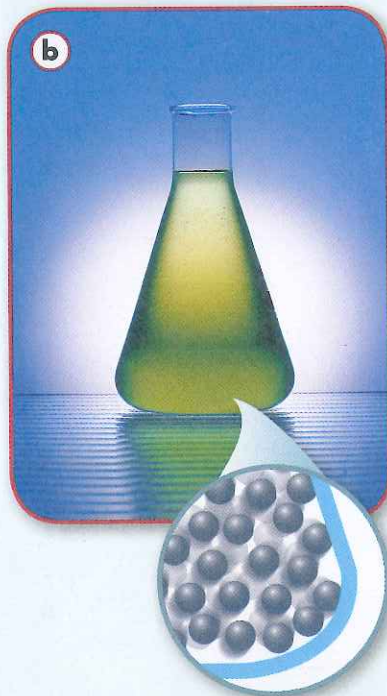
See states of matter animated online.



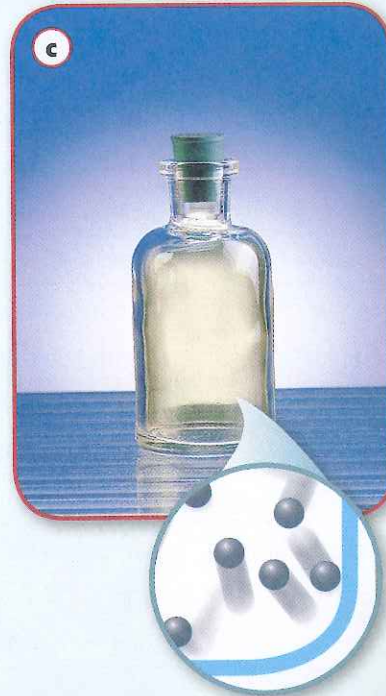
Solid In a solid, the particles are packed closely together in a rigid arrangement.



Liquid In a liquid, the particles are close together, but they are free to flow past one another.



Gas In a gas, the particles are relatively far apart and can move freely.



Gases Like a liquid, a gas takes the shape of its container. But unlike a liquid, a gas can expand to fill any volume. A **gas** is a form of matter that takes both the shape and volume of its container. Look back at Figure 2.3c. As shown in the model, the particles in a gas are usually much farther apart than the particles in a liquid. Because of the space between particles, gases are easily compressed into a smaller volume.

The words *vapor* and *gas* are sometimes used interchangeably. But there is a difference. The term *gas* is used for substances, like oxygen, that exist in the gaseous state at room temperature. (*Gaseous* is the adjective form of *gas*.) **Vapor** describes the gaseous state of a substance that is generally a liquid or solid at room temperature, as in *water vapor*.

Physical Changes

Key How can physical changes be classified?

The melting point of gallium metal is 30°C. Figure 2.4 shows how heat from a person's hand can melt a sample of gallium. The shape of the sample changes during melting as the liquid begins to flow, but the composition of the sample does not change. Melting is a physical change. During a **physical change**, some properties of a material change, but the composition of the material does not change.

Words such as *boil*, *freeze*, *melt*, and *condense* are used to describe physical changes. So are words such as *break*, *split*, *grind*, *cut*, and *crush*. However, there is a difference between these two sets of words. Each set describes a different type of physical change. **Physical changes can be classified as reversible or irreversible.** Melting is an example of a reversible physical change. If a sample of liquid gallium is cooled below its melting point, the liquid will become a solid. All physical changes that involve a change from one state to another are reversible. Cutting hair, filing nails, and cracking an egg are examples of irreversible physical changes.

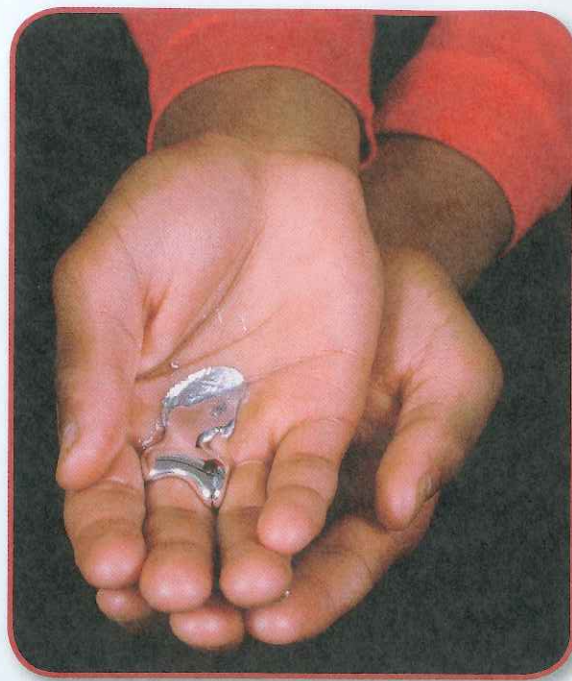


Figure 2.4 Physical Change
The silvery substance in the photograph is gallium, which has a melting point of 30°C.
Infer What can you infer about the temperature of the hand holding the gallium?



2.1 LessonCheck

- 1. Explain** Explain why all samples of a given substance have the same intensive properties.
- 2. Identify** Name three states of matter.
- 3. Describe** Describe the two categories used to classify physical changes.
- 4. Identify** Name two categories used to classify properties of matter.
- 5. Interpret Tables** Which property in Table 2.1 can most easily distinguish sodium chloride from the other solids?
- 6. Compare and Contrast** In what way are liquids and gases alike? In what way are liquids and solids different?
- 7. Explain** Is the freezing of mercury a reversible or irreversible physical change? Explain your answer.
- 8. Explain** Explain why samples of platinum and copper can have the same extensive properties but not the same intensive properties.

BIG IDEA

CHEMISTRY AS THE CENTRAL SCIENCE

- 9.** How would understanding the properties of matter be helpful in other fields of study besides chemistry?

2.2 Mixtures



CHEMISTRY & YOU

Q: *Why aren't there coffee grounds in a cup of coffee?* Coffee is often brewed by mixing hot water with ground coffee beans. But when people drink coffee, the grounds are usually not in their mug. In this lesson, you will learn how to classify and separate mixtures.

Key Questions

Key How can mixtures be classified?

Key How can mixtures be separated?

Vocabulary

- mixture
- heterogeneous mixture
- homogeneous mixture
- solution
- phase
- filtration
- distillation

Classifying Mixtures

Key How can mixtures be classified?

A salad bar, like the one in Figure 2.5, provides a range of items, such as lettuce, tomatoes, cheese, and green peppers. Customers choose which items to use in their salads and how much of each item to use. So each salad mixture has different types and amounts of components. A **mixture** is a physical blend of two or more components.

Most samples of matter are mixtures. Some mixtures are easier to recognize than others. You can easily recognize chicken noodle soup as a mixture of chicken, noodles, and broth. Recognizing air as a mixture of gases is more difficult. But the fact that air can be drier or more humid shows that the amount of one component of air—water vapor—can vary. Chicken noodle soup and air represent two different types of mixtures. **Key** Based on the distribution of their components, mixtures can be classified as heterogeneous mixtures or as homogeneous mixtures.

Figure 2.5
Salads Are Mixtures

You can choose the amount of each item you select from a salad bar. So your salad is unlikely to have the same composition as other salads containing the same items.

Quick Lab

Purpose To separate a mixture using paper chromatography

Materials

- green marking pen
- filter paper strip
- metric ruler
- clear plastic tape
- pencil
- rubbing alcohol
- clear plastic drinking cup
- clear plastic wrap



Separating Mixtures

Procedure

1. Use the marking pen to draw a line across a strip of filter paper, as shown in the drawing. The line should be 2 cm from one end of the strip.
2. Tape the unmarked end of the filter paper to the center of a pencil so that the strip hangs down when the pencil is held horizontally, as shown in the diagram below.

3. Working in a well-ventilated room, pour rubbing alcohol into a plastic cup to a depth of 1 cm.
4. Rest the pencil on the rim of the cup so that the ink end of the strip touches the rubbing alcohol but does not extend below its surface. Use plastic wrap to cover the top of the cup.
5. Observe the setup for 15 minutes.

Analyze and Conclude

1. **Identify** How did the appearance of the filter paper change during the procedure?
2. **Analyze Data** What evidence is there that green ink is a mixture?
3. **Apply Concepts** How could you use this procedure to identify an unknown type of green ink?

Heterogeneous Mixtures In chicken noodle soup, the ingredients in the soup are not evenly distributed throughout the mixture. There is likely to be different amounts of chicken and noodles in each spoonful. A mixture in which the composition is not uniform throughout is a **heterogeneous mixture**.

Homogeneous Mixtures The substances in the olive oil in Figure 2.6 are evenly distributed throughout the mixture. So, olive oil doesn't look like a mixture. The same is true for vinegar. Vinegar is a mixture of water and acetic acid, which dissolves in the water. Olive oil and vinegar are homogeneous mixtures. A **homogeneous mixture** is a mixture in which the composition is uniform throughout. Another name for a homogeneous mixture is a **solution**. Many solutions are liquids. But some are gases, like air, and some are solids, like stainless steel, which is a mixture of iron, chromium, and nickel.

The term **phase** is used to describe any part of a sample with uniform composition and properties. By definition, a homogeneous mixture consists of a single phase. A heterogeneous mixture consists of two or more phases. When oil and vinegar are mixed, they form a heterogeneous mixture with two layers, or phases. As shown in Figure 2.6, the oil phase floats on the water, or vinegar, phase.



Figure 2.6 Homogeneous Mixtures Olive oil and vinegar are homogeneous mixtures. The substances in these mixtures are evenly distributed. When olive oil and vinegar are mixed, they form a heterogeneous mixture with two distinct phases.



Figure 2.7 Filtration
A filter is used to separate ground coffee beans from brewed coffee. This process is a type of filtration.

Separating Mixtures

Key How can mixtures be separated?

If you have a salad containing an ingredient you don't like, you can use a fork to remove the pieces of the unwanted ingredient. Many mixtures are not as easy to separate. To separate a mixture of olive oil and vinegar, for example, you could decant, or pour off, the oil layer. Or you might cool the mixture until the oil turned solid. The first method takes advantage of the fact that oil floats on water. The second method takes advantage of a difference in the temperatures at which the olive oil and vinegar freeze. **Key** Differences in physical properties can be used to separate mixtures.

Filtration The coffee filter in Figure 2.7 can separate ground coffee beans from brewed coffee. The liquid brewed coffee passes through the paper filter, but the solid coffee grounds cannot pass through the filter. Filter paper used in a laboratory is similar to coffee filters. Filter paper is often placed in a funnel. Then the mixture is poured into the funnel. Solid particles that cannot pass through the filter remain in the funnel. The rest of the particles in solution pass through the filter paper. The process that separates a solid from the liquid in a heterogeneous mixture is called **filtration**.

Distillation Tap water is a homogeneous mixture of water and substances that are dissolved in the water. One way to separate water from the other components in tap water is through a process called distillation. During a **distillation**, a liquid is boiled to produce a vapor that is then condensed into a liquid. Figure 2.8 shows an apparatus that can be used to perform a small-scale distillation.

As water in the distillation flask is heated, water vapor forms, rises in the flask, and passes into a glass tube in the condenser. The tube is surrounded by cold water, which cools the vapor to a temperature at which it turns back into a liquid. The liquid water is collected in a second flask. The solid substances that were dissolved in the water remain in the distillation flask because their boiling points are much higher than the boiling point of water.

CHEMISTRY & YOU

Q: Brewing coffee is a mixture of ground coffee beans and water. What process is used to separate ground coffee beans from brewed coffee?

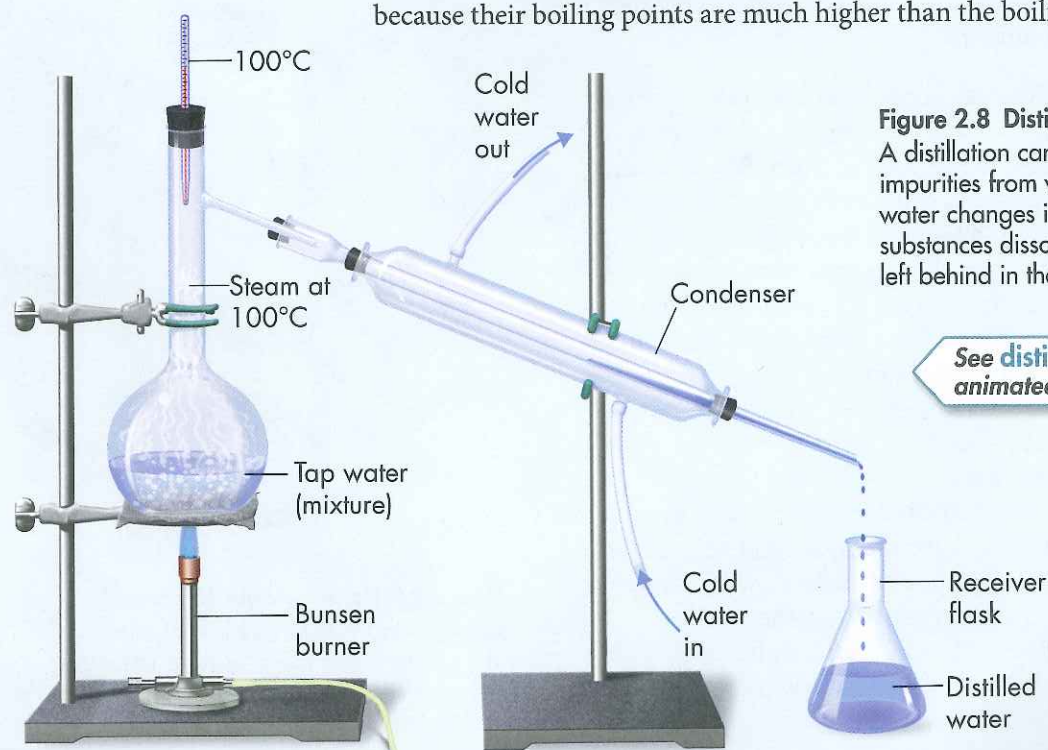


Figure 2.8 Distillation
A distillation can be used to remove impurities from water. As liquid water changes into water vapor, substances dissolved in the water are left behind in the distillation flask.

See distillation animated online.



Sample Problem 2.1

Separating a Heterogeneous Mixture

How could a mixture of aluminum nails and iron nails be separated?

1 Analyze Identify the relevant concepts. In order to identify how to separate aluminum and iron nails, the properties of both aluminum and iron must be known.

2 Solve Apply concepts to this situation.

List the properties of each substance in the mixture.

Aluminum

- metal
- gray color
- doesn't dissolve in water
- not attracted to magnet

Iron

- metal
- gray color
- doesn't dissolve in water
- attracted to magnet

Identify a property that can be used to separate different substances from each other.

The ability to be attracted by a magnet is a property that iron and aluminum do not share. You could use a magnet to remove the iron nails from a mixture of iron and aluminum.

10. What physical properties could be used to separate iron filings from table salt?



11. Air is mainly a mixture of nitrogen and oxygen, with small amounts of other gases such as argon and carbon dioxide. What property could you use to separate the gases in air?



2.2 LessonCheck

12. Identify How are mixtures classified?

13. List What type of properties can be used to separate mixtures?

14. Explain Explain the term *phase* as it relates to homogeneous and heterogeneous mixtures.

15. Classify Classify each of the following as a homogeneous or heterogeneous mixture.

- food coloring
- ice cubes in liquid water
- mouthwash
- mashed, unpeeled potatoes

16. Compare and Contrast How are a substance and a solution similar? How are they different?

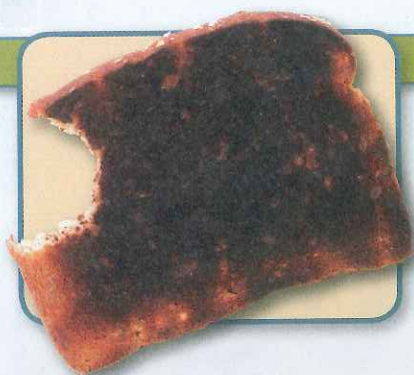
17. Apply Concepts In general, when would you use filtration to separate a mixture? When would you use distillation to separate a mixture?

18. Explain Describe a procedure that could be used to separate a mixture of sand and table salt.

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19. Give three examples of when you have separated mixtures at home.

2.3 Elements and Compounds



CHEMISTRY & YOU

Q: *Why does burned toast taste so bad?* Bread that is toasted to a nice golden brown makes for a tasty addition to breakfast. But most people would agree that bread that is cooked so long that it is burned and black is not tasty.

Distinguishing Elements and Compounds

Key Question: *How are elements and compounds different?*

Substances can be classified as elements or compounds. An **element** is the simplest form of matter that has a unique set of properties. Oxygen and hydrogen are two of the more than 100 known elements. A **compound** is a substance that contains two or more elements chemically combined in a fixed proportion. For example, carbon, oxygen, and hydrogen are chemically combined in the compound sucrose. Sometimes sucrose is called table sugar to distinguish it from other sugar compounds. In every sample of sucrose, there are twice as many hydrogen particles as oxygen particles. The proportion of hydrogen particles to oxygen particles in sucrose is fixed. There is a key difference between elements and compounds. **Compounds can be broken down into simpler substances by chemical means, but elements cannot.**

Breaking Down Compounds Physical methods that are used to separate mixtures cannot be used to break a compound into simpler substances. Boil liquid water and you get water vapor, not the oxygen and hydrogen that water contains. Dissolve a sugar cube in water and you still have sucrose, not oxygen, carbon, and hydrogen. This result does not mean that sucrose or water cannot be broken down into simpler substances. But the methods must involve a chemical change.

Key Questions

Key Question: *How are elements and compounds different?*

Key Question: *How can substances and mixtures be distinguished?*

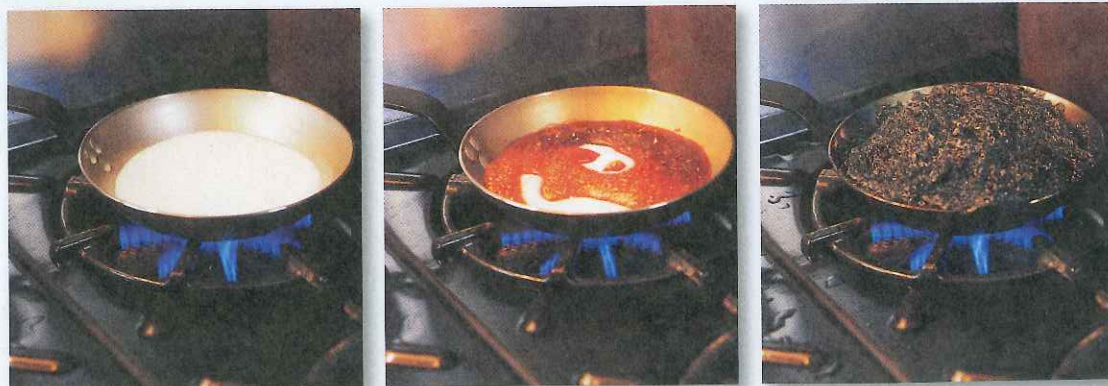
Key Question: *What do chemists use to represent elements and compounds?*

Key Question: *Why is a periodic table useful?*

Vocabulary

- element
- compound
- chemical change
- chemical symbol
- periodic table
- period
- group

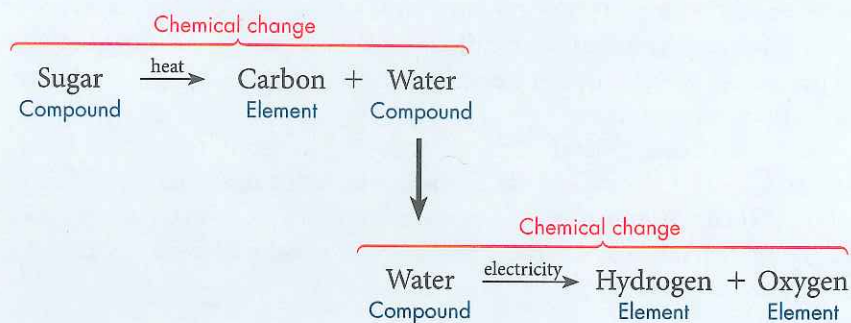
Figure 2.9
Chemical Changes
When table sugar is heated, it goes through a series of chemical changes. The final products of these changes are solid carbon and water vapor.



Q: What happens to the compounds in bread when it is overcooked that causes the changes to the taste of the bread?

A **chemical change** is a change that produces matter with a different composition than the original matter. Heating is one of the processes used to break down compounds into simpler substances. The layer of sugar in Figure 2.9 is heated in a skillet until it breaks down into solid carbon and water vapor. Can the substances that are produced also be broken down?

There is no chemical process that will break down carbon into simpler substances because carbon is an element. Heat will not cause water to break down, but electricity will. When an electric current passes through water, oxygen gas and hydrogen gas are produced. The following diagram summarizes the overall process.



Properties of Compounds In general, the properties of compounds are quite different from those of their component elements. Sugar is a sweet-tasting, white solid, but carbon is a black, tasteless solid. Hydrogen is a gas that burns in the presence of oxygen—a colorless gas that supports burning. The product of this chemical change is water, a liquid that can stop materials from burning. Figure 2.10 shows samples of table salt (sodium chloride), sodium, and chlorine. When the elements sodium and chlorine combine chemically to form sodium chloride, there is a change in composition and a change in properties. Sodium is a soft, gray metal. Chlorine is a pale yellow-green poisonous gas. Sodium chloride is a white solid.

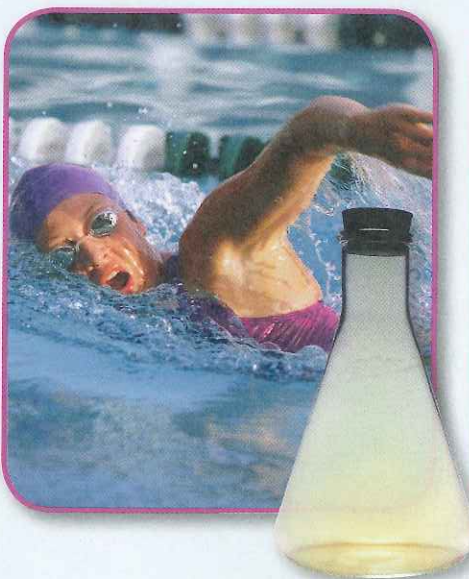
Figure 2.10 Properties of Compounds and Their Elements Compounds and the elements from which they form have different properties. The elements sodium and chlorine have different properties from each other and from the compound sodium chloride.

Observe Based on the photographs, describe two physical properties of sodium and two of chlorine.

Sodium is stored under oil to keep it from reacting with oxygen or water vapor in air. Sodium vapor produces the light in some street lamps.

Chlorine is used to make compounds that kill harmful organisms in swimming pools.

Sodium chloride (commonly known as table salt) is a compound used to season or preserve food.



Distinguishing Substances and Mixtures

Key How can substances and mixtures be distinguished?

Deciding whether a sample of matter is a substance or a mixture based solely on appearance can be difficult. After all, homogeneous mixtures and substances will both appear to contain only one kind of matter. Sometimes you can decide by considering whether there is more than one version of the material in question. For example, you can buy whole milk, low-fat milk, no-fat milk, light cream, or heavy cream. From this information, you can conclude that milk and cream are mixtures. You might infer that these mixtures differ in the amount of fat they contain. Most gas stations offer at least two blends of gasoline. The blends have different octane ratings and different costs per gallon, with premium blends costing more than regular blends. So gasoline must be a mixture.

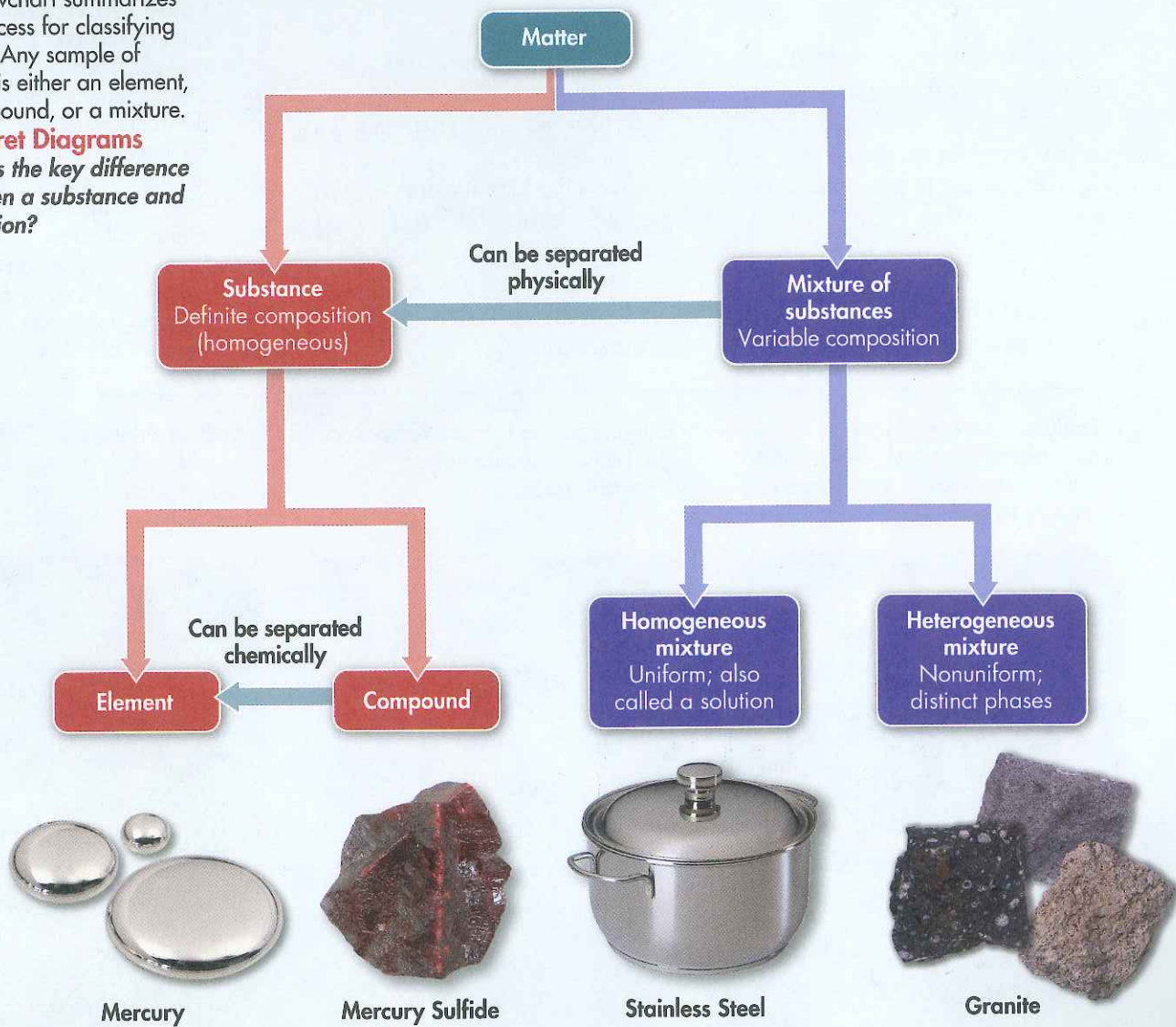
You can use their general characteristics to distinguish substances from mixtures. **Key** If the composition of a material is fixed, the material is a substance. If the composition of a material may vary, the material is a mixture. Figure 2.11 summarizes the general characteristics of elements, compounds, and mixtures.

Figure 2.11 Element, Compound, or Mixture?

The flowchart summarizes the process for classifying matter. Any sample of matter is either an element, a compound, or a mixture.

Interpret Diagrams

What is the key difference between a substance and a solution?



Sample Problem 2.2

Classifying Materials

When a certain blue-green solid is heated, a colorless gas and a black solid form. All three materials are substances. Is it possible to classify these substances as elements or compounds?

1 Analyze Identify the relevant concepts. A compound can be broken down into simpler substances by a chemical change, but an element cannot. Heating can cause a chemical change.

2 Solve Apply concepts to this situation.

List the known facts and relevant concepts.

Determine if the substances are elements or compounds.

• A blue-green solid is heated.

• A colorless gas and a black solid appear.

Before heating, there was one substance. After heating, there were two substances. The blue-green solid must be a compound. Based on the information given, it isn't possible to know if the colorless gas and the black solid are elements or compounds.

A compound is made of two or more elements that are chemically combined.



20. Liquid A and Liquid B are clear liquids. They are placed in open containers and allowed to evaporate. When evaporation is complete, there is a white solid in container B but no solid in container A. From these results, what can you infer about the two liquids?

21. A clear liquid in an open container is allowed to evaporate. After three days, a solid is left in the container. Was the clear liquid an element, a compound, or a mixture? How do you know?

Symbols and Formulas

Key What do chemists use to represent elements and compounds?

The common names *water* and *table salt* do not provide information about the chemical composition of these substances. Also, words are not ideal for showing what happens to the composition of matter during a chemical change. **Chemists use chemical symbols to represent elements, and chemical formulas to represent compounds.**

Using symbols to represent different kinds of matter is not a new idea. For thousands of years, alchemists used symbols, such as the ones in Figure 2.12, to represent elements. The symbols used today for elements are based on a system developed by a Swedish chemist, Jöns Jacob Berzelius (1779–1848). He based his symbols on the Latin names of elements. Each element is represented by a one- or two-letter **chemical symbol**. The first letter of a chemical symbol is always capitalized. When a second letter is used, it is lowercase.

Figure 2.12 Element Symbols The symbols used to represent elements have changed over time. Alchemists and the English chemist John Dalton (1766–1844) both used drawings to represent chemical elements. Today, elements are represented by one- or two-letter symbols.

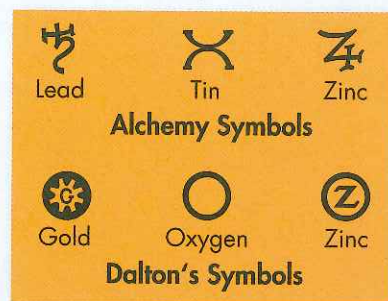


Table 2.2

Symbols and Latin Names for Some Elements

Name	Symbol	Latin name
Sodium	Na	<i>natrium</i>
Potassium	K	<i>kalium</i>
Antimony	Sb	<i>stibium</i>
Copper	Cu	<i>cuprum</i>
Gold	Au	<i>aurum</i>
Silver	Ag	<i>argentum</i>
Iron	Fe	<i>ferrum</i>
Lead	Pb	<i>plumbum</i>
Tin	Sn	<i>stannum</i>

If the English name and the Latin name of an element are similar, the symbol will appear to have been derived from the English name. Examples include Ca for calcium, N for nitrogen, and S for sulfur. Table 2.2 shows examples of elements for which the symbols do not match the English names. Chemical symbols provide a shorthand way to write the chemical formulas of compounds. The symbols for hydrogen, oxygen, and carbon are H, O, and C. The formula for water is H_2O . The formula for sucrose, or table sugar, is $C_{12}H_{22}O_{11}$. Subscripts in chemical formulas tell you how many of each type of element are in the compound. For example, the subscript 2 in H_2O indicates that there are always two parts of hydrogen for each part of oxygen in water. Because a compound has a fixed composition, the formula for a compound is always the same.

The Periodic Table—A Preview

Why is a periodic table useful?


All the known elements are organized in a special table called the periodic table. A **periodic table** is an arrangement of elements in which the elements are separated into groups based on a set of repeating properties.  **The periodic table allows you to easily compare the properties of one element (or a group of elements) to another element (or group of elements).**

Figure 2.13 shows the most commonly used form of the modern periodic table, sometimes called the long form. Each element is identified by its symbol placed in a square. The elements are listed in order from left to right and top to bottom by atomic number, a number that is unique to each element. The atomic number of the element is shown centered above the symbol. You will learn more about atomic numbers in Chapter 4. Hydrogen (H), the lightest element, is in the top left corner. Helium (He), atomic number 2, is at the top right. Lithium (Li), atomic number 3, is at the left end of the second row.

Each horizontal row of the periodic table is called a **period**. There are seven periods in the periodic table. The number of elements per period ranges from 2 (hydrogen and helium) in Period 1 to 32 in Period 6. Within a period, the properties of the elements vary as you move across the period. This pattern of properties then repeats as you move to the next period.

Each vertical column of the periodic table is called a **group**, or family. Elements within a group have similar chemical and physical properties. Note that each group is identified by a number and the letter A or B. For example, Group 2A contains the elements beryllium (Be), magnesium (Mg), calcium (Ca), strontium (Sr), barium (Ba), and radium (Ra). You will learn more about specific trends in the periodic table in Chapter 6.

Figure 2.13 The Periodic Table
Elements are arranged in the modern periodic table in order of atomic number.
Interpret Diagrams How many elements are in Period 2? In Group 2A?

1A																	8A		
1	1 H																	2 He	
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne	
3	11 Na	12 Mg	3B	4B	5B	6B	7B	8B			1B	2B	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar	
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr	
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe	
6	55 Cs	56 Ba	71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn	
7	87 Fr	88 Ra	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Uuq	115 Uup	116 Uuh	118 Uuo		
			57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb			
			89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No			



2.3 LessonCheck

- 22. Compare** How is a compound different from an element?
- 23. Compare** How can you distinguish a substance from a mixture?
- 24. Identify** What are chemical symbols and chemical formulas used for?
- 25. Explain** What makes the periodic table such a useful tool?
- 26. Identify** Name two methods that can be used to break down compounds into simpler substances.
- 27. Classify** Classify each of these samples of matter as an element, a compound, or a mixture.
 - table sugar
 - tap water
 - cough syrup
 - nitrogen
- 28. Identify** Write the chemical symbol for each of the following elements:
 - lead
 - oxygen
 - silver
 - sodium
 - hydrogen
 - aluminum
- 29. Identify** Name the chemical elements represented by the following symbols:
 - C
 - Ca
 - K
 - Au
 - Fe
 - Cu
- 30. Identify** What elements make up the pain reliever acetaminophen, chemical formula $C_8H_9O_2N$? Which element is present in the greatest proportion by number of particles?
- 31. Identify** Name two elements that have properties similar to those of the element calcium (Ca).

2.4 Chemical Reactions



CHEMISTRY & YOU

Q: *What happened to the match?* Matches are often used to light candles on a cake. A match is usually lit at the tip and then burns down the match. So you better be quick, or your fingers will be burned by the lit match. A lit match is different than an unlit match. In this lesson, you will learn to recognize whether the burning match is a chemical change or physical change.

Key Questions

Key What always happens during a chemical change?

Key What are four possible clues that a chemical change has taken place?

Key How are the mass of the reactants and the mass of the products of a chemical reaction related?

Vocabulary

- chemical property
- chemical reaction
- reactant
- product
- precipitate
- law of conservation of mass

READING SUPPORT

Build Study Skills: Preview Visuals Before you start reading the lesson, preview the visuals in Figure 2.16. Then write two questions you have about the visuals. After you finish reading, answer your questions.

Chemical Changes

Key What always happens during a chemical change?

The compound formed when iron rusts is iron oxide (Fe_2O_3). Words such as *burn*, *rot*, *rust*, *decompose*, *ferment*, *explode*, and *corrode* usually signify a chemical change. The ability of a substance to undergo a specific chemical change is called a **chemical property**. Iron is able to combine with oxygen to form rust. So the ability to rust is a chemical property of iron. Chemical properties can be used to identify a substance. But chemical properties can be observed only when a substance undergoes a chemical change.

Figure 2.14 compares a physical change and a chemical change that can occur in a sample of charcoal. When charcoal is broken into smaller pieces, the change is a physical change. The substances present before the change are the same substances present after the change, although the charcoal pieces are not as large. Recall that during a physical change, the composition of matter never changes. **Key** During a chemical change, the composition of matter always changes. When the charcoal is heated and burned, a chemical change occurs. The substances in charcoal react with oxygen in the air to form other substances.

A chemical change is also called a chemical reaction. One or more substances change into one or more new substances during a **chemical reaction**. A substance present at the start of the reaction is a **reactant**. A substance produced in the reaction is a **product**. In the burning of charcoal, carbon and oxygen are the main reactants, and carbon dioxide is the main product.

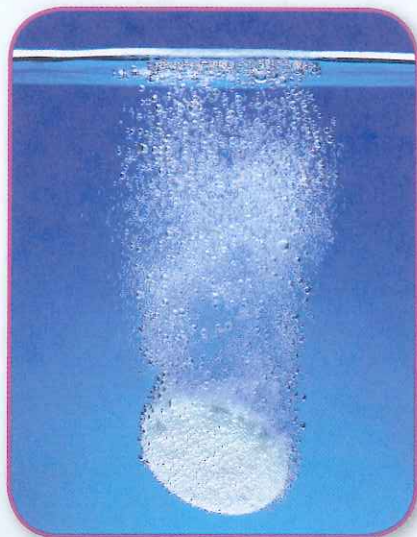
Figure 2.14
Physical and Chemical Changes
Charcoal is used as a fuel in charcoal grills. **a.** Breaking the charcoal into smaller pieces is a physical change. **b.** Burning the charcoal is a chemical change.



Figure 2.15 Chemical Change

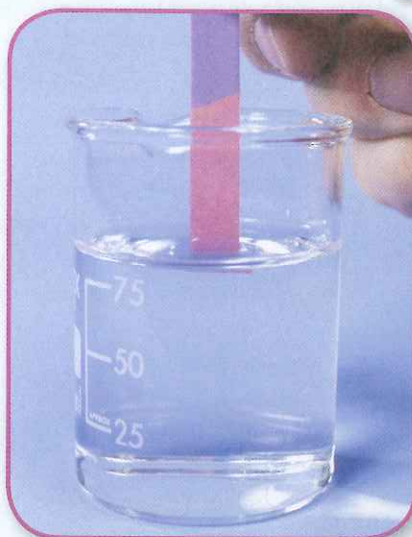
Clues to chemical change often have practical applications.

Learn more about physical and chemical changes online.



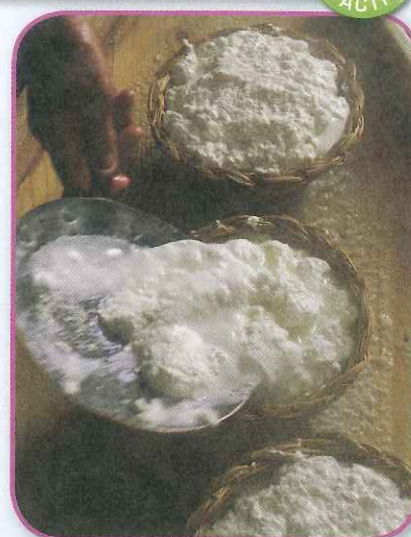
Production of a Gas

Bubbles of carbon dioxide gas form when an antacid tablet is dropped into a glass of water.



Color Change

When a test strip is dipped in a solution, the color change is used to determine the pH of the solution.




Formation of a Precipitate

One step in the production of cheese is a reaction that causes milk to separate into solid curds and liquid whey.

Recognizing Chemical Changes

 **What are four possible clues that a chemical change has taken place?**

How can you tell whether a chemical change has taken place? There are four clues that can serve as a guide.  **Possible clues to chemical change include a transfer of energy, a change in color, the production of a gas, or the formation of a precipitate.**

Every chemical change involves a transfer of energy. For example, energy stored in natural gas is used to cook food. When the methane in natural gas chemically combines with oxygen in the air, energy is given off in the form of heat and light. Some of this energy is transferred to and absorbed by food that is cooking over a lit gas burner. The energy causes chemical changes to take place in the food. The food may change color and brown as it cooks, which is another clue that chemical changes are occurring.

You can observe two other clues to chemical change while cleaning a bathtub. The ring of soap scum that can form in a bathtub is an example of a precipitate. A **precipitate** is a solid that forms and settles out of a liquid mixture. Some bathroom cleaners that you can use to remove soap scum start to bubble when you spray them on the scum. The bubbles are produced because a gas is released during the chemical change that is taking place in the cleaner.

If you observe a clue to chemical change, you cannot be certain that a chemical change has taken place. The clue may be the result of a physical change. For example, energy is always transferred when matter changes from one state to another. Bubbles form when you boil water or open a carbonated drink. The only way to be sure that a chemical change has occurred is to test the composition of a sample before and after the change. Figure 2.15 shows examples of practical situations in which different clues to chemical change are visible.

CHEMISTRY & YOU

Q: Are the changes that happen to a burning match chemical changes or physical changes? How do you know?

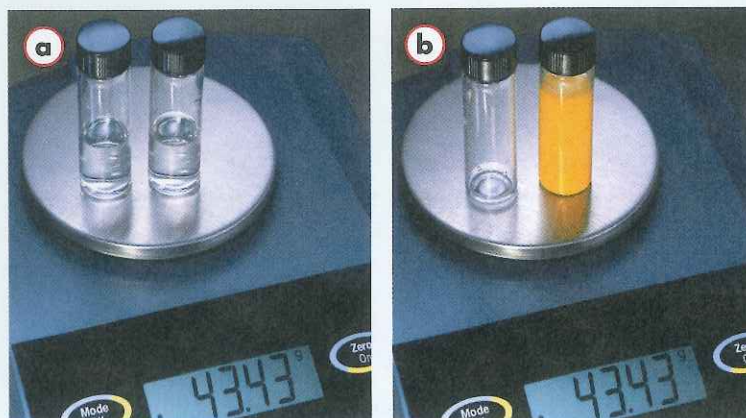
Conservation of Mass

Key How are the mass of the reactants and the mass of the products of a chemical reaction related?

When wood burns, substances in the wood combine with oxygen from the air. As the wood burns, a sizable amount of matter is reduced to a small pile of ashes. The reaction seems to involve a reduction in the amount of matter. But appearances can be deceiving. **Key** During any chemical reaction, the mass of the products is always equal to the mass of the reactants. Two of the products of burning wood—carbon dioxide gas and water vapor—are released into the air. When the mass of these gases is considered, the amount of matter is unchanged. Careful measurements show that the total mass of the reactants (wood and the oxygen consumed) equals the total mass of the products (carbon dioxide, water vapor, and ash).

Mass also holds constant during physical changes. For example, when 10 grams of ice melt, 10 grams of liquid water are produced. Similar observations have been recorded for all chemical and physical changes studied. The scientific law that reflects these observations is the law of conservation of mass. The **law of conservation of mass** states that in any physical change or chemical reaction, mass is conserved. Mass is neither created nor destroyed. The conservation of mass is more easily observed when a change occurs in a closed container, as in Figure 2.16.

Figure 2.16
Conservation of Mass
When the liquids in **a**. are mixed, they react. The products are shown in **b**. None of the products are gases.
Analyze Data How do you know that a reaction took place and that mass was conserved during the reaction?



2.4 LessonCheck

- 32. Explain** How does a chemical change affect the composition of matter?
- 33. List** Name four possible clues that a chemical change has taken place.
- 34. Compare** In a chemical reaction, how does the mass of the reactants compare with the mass of the products?
- 35. Compare** What is the main difference between physical changes and chemical changes?
- 36. Classify** Classify the following changes as physical or chemical changes.
- a. Water boils. c. Milk turns sour.
b. Salt dissolves in water. d. A metal rusts.
- 37. Explain** According to the law of conservation of mass, when is mass conserved?
- 38. Calculate** Hydrogen and oxygen react chemically to form water. How much water would form if 4.8 grams of hydrogen reacted with 38.4 grams of oxygen?



Small-Scale Lab

1 + 2 + 3 = Black!

Purpose

To make macroscopic observations of chemical reactions and use them to solve problems

Materials

- paper
- metric ruler
- reaction surface
- materials shown in grid
- pipette, medicine droppers, and spatulas

Procedure



1. Draw two copies of the grid on separate sheets of paper. Make each square in the grid 2 cm on each side.
2. Place a reaction surface over one of the grids. Use the second grid as a data table to record your observations.
3. Use the column and row labels to determine which materials belong in each square. Depending on the material, add one drop, one piece, or a few grains.
4. Stir each mixture by forcing air from an empty pipette as directed by your teacher.

	NaClO	H ₂ O ₂	CuSO ₄
KI			
KI + Starch			
KI + Paper			
KI + Cereal			



Analyze

Using your experimental data, record the answers to the following questions below your data table.

1. **Describe** What color is a mixture of sodium hypochlorite (NaClO) and potassium iodide (KI)?
2. **Describe** What happens when you mix NaClO, KI, and starch?
3. **Compare** What do NaClO, H₂O₂, and CuSO₄ have in common?
4. **Compare** What substance is found in both paper and cereal? How do you know?
5. **Predict** If you used NaClO instead of CuSO₄ in reactions other than the reaction with KI and starch, would you expect the results to always be identical? Explain your answer.

You're the Chemist

The following small-scale activities allow you to develop your own procedures and analyze the results.

1. **Analyze Data** NaClO is a bleaching agent. Such agents are used to whiten clothes and remove stains. Use different color marker pens to draw several lines on a piece of white paper. Add one drop of NaClO to each line. What happens? Try inventing a technique that you can use to make "bleach art."
2. **Design an Experiment** Design and carry out an experiment to see which foods contain starch.
3. **Design an Experiment** Read the label on a package of iodized salt. How much KI does iodized salt contain? Design an experiment to demonstrate the presence of KI in iodized salt and its absence in salt that is not iodized.
4. **Design an Experiment** Antacid tablets often contain starch as a binder to hold the ingredients in the tablet together. Design and carry out an experiment to explore various antacid tablets to see if they contain starch.

Recycled Mixtures

You may be used to sorting recyclables into separate bins. But now, a new process known as single-stream recycling allows you to put all recyclables into a single container. The separation is then done at a plant known as a Material Recovery Facility (MRF), which uses machines to separate paper, glass, metal, and plastics based on their properties.



1. FEEDER Unsorted paper, glass, plastic, and metal are loaded onto a conveyer belt. In some locations, workers pull any mixed-in trash off the belt and discard it.

2. SCREENING MACHINES A series of fast, rotating rubber blades, called star screens, separate out cardboard, newspaper, and other paper from the rest of the material. The plastic, glass, and metals fall through the screens onto another conveyer belt.

3. ELECTROMAGNET Heavy-duty electro-magnets grab items made of ferrous metals, such as iron and steel, off the conveyer belt.

4. EDDY CURRENT A rotating magnetic field creates an eddy current that repels nonmagnetic metals, such as aluminum, and ejects them from the rest of the materials.

5. GLASS CRUSHER The remaining materials move through another series of screens designed to break glass and remove it from the stream.

6. OPTICAL SCANNER Optical scanners use infrared technology to recognize different types or colors of plastics and can trigger blasts of air to separate the plastics into bins.

Take It Further

- 1. Identify** What are three properties of matter that are used to help sort materials during the single-stream recycling process?
- 2. Describe** What are some possible benefits of single-stream recycling vs. regular recycling?



CARDBOARD,
PAPER AND
NEWSPAPER BALER

FERROUS METALS
BALER

ALUMINUM BALER

GLASS BALER

PLASTICS BALER

7. BALERS After the products are separated, they're stored and fed into balers, which bundle the materials together. The materials are then shipped out to recycling plants, where they will be made into new products.

2 Study Guide

BIG IDEA

CHEMISTRY AS THE CENTRAL SCIENCE

Physical properties, such as melting point and boiling point, and chemical properties, such as whether a substance will corrode or burn, are used to describe matter. Matter may be made of elements or compounds. Elements and compounds are pure substances but can be physically combined to make heterogeneous or homogeneous mixtures. These different forms of matter may undergo physical or chemical changes.

2.1 Properties of Matter

Every sample of a given substance has identical intensive properties because every sample has the same composition.

Three states of matter are solid, liquid, and gas.

Physical changes can be classified as reversible or irreversible.

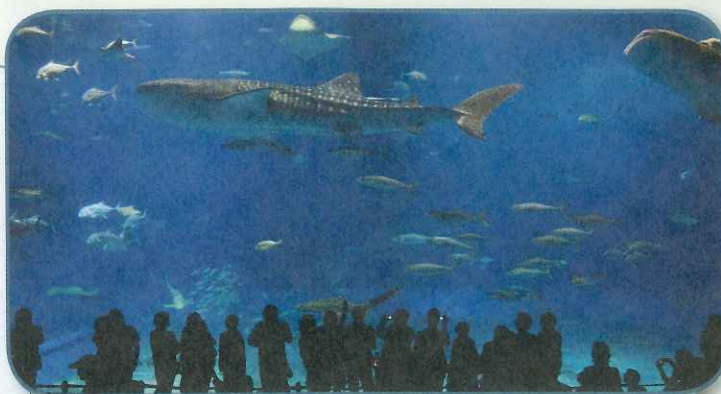
- mass (34)
- volume (34)
- extensive property (34)
- intensive property (34)
- substance (35)
- physical property (35)
- solid (36)
- liquid (36)
- gas (37)
- vapor (37)
- physical change (37)

2.2 Mixtures

Mixtures can be classified as heterogeneous mixtures or as homogeneous mixtures, based on the distribution of their components.

Differences in physical properties can be used to separate mixtures.

- mixture (38)
- heterogeneous mixture (39)
- homogeneous mixture (39)
- solution (39)
- phase (39)
- filtration (40)
- distillation (40)



2.3 Elements and Compounds

Compounds can be broken down into simpler substances by chemical means, but elements cannot.

If the composition of a material is fixed, the material is a substance. If the composition may vary, the material is a mixture.

Chemists use chemical symbols to represent elements, and chemical formulas to represent compounds.

The periodic table allows you to easily compare the properties of one element (or a group of elements) to another element (or group of elements).

- element (42)
- compound (42)
- chemical change (43)
- chemical symbol (45)
- periodic table (46)
- period (46)
- group (47)

2.4 Chemical Reactions

During a chemical change, the composition of matter always changes.

Four possible clues to chemical change include a transfer of energy, a change in color, the production of a gas, or the formation of a precipitate.

During any chemical reaction, the mass of the products is always equal to the mass of the reactants.

- chemical property (48)
- chemical reaction (48)
- reactant (48)
- product (48)
- precipitate (49)
- law of conservation of mass (50)



2 Assessment

* Solutions appear in Appendix E

Lesson by Lesson

2.1 Properties of Matter

39. Describe the difference between an extensive property and an intensive property and give an example of each.
40. List three physical properties of copper.
41. Name two physical properties that could be used to distinguish between water and ethanol.
- *42. Name one physical property that could not be used to distinguish chlorine from oxygen.
43. What is the physical state of each of these materials at room temperature?
 - a. gold
 - b. gasoline
 - c. oxygen
 - d. neon
 - e. olive oil
 - f. sulfur
 - g. mercury
- *44. Fingernail-polish remover (mostly acetone) is a liquid at room temperature. Would you describe acetone in the gaseous state as a vapor or a gas? Explain your answer.
45. Compare the arrangements of individual particles in solids, liquids, and gases.
46. Use Table 2.1 to identify four substances that undergo a physical change if the temperature is reduced from 50°C to -50°C . What is the physical change that takes place in each case?
- *47. Explain why sharpening a pencil is a different type of physical change than freezing water to make ice cubes.

2.2 Mixtures

48. What is the difference between homogeneous mixtures and heterogeneous mixtures?
49. How many phases does a solution have? Explain your answer.

- *50. Classify each of the following as a homogeneous or heterogeneous mixture.
 - a. chocolate-chip ice cream
 - b. green ink
 - c. cake batter
 - d. cooking oil
 - e. granite rock
 - f. salt water
 - g. paint
 - h. a silver ring
51. What is the goal of a distillation? Describe briefly how this goal is accomplished.

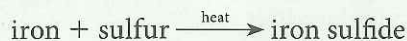
2.3 Elements and Compounds

52. How could you distinguish an element from a compound?
- *53. Classify the following materials as an element, compound, or mixture. Give reasons for your answers.
 - a. table salt (NaCl)
 - b. salt water
 - c. sodium (Na)
54. Describe the relationship between the three items in each of the following groups. Identify each item as an element, compound, or mixture.
 - a. hydrogen, oxygen, and water
 - b. nitrogen, oxygen, and air
 - c. sodium, chlorine, and table salt
 - d. carbon, water, and table sugar
55. Name the elements found in each of the following compounds.
 - a. ammonia (NH_3)
 - b. potassium oxide (K_2O)
 - c. sucrose ($\text{C}_{12}\text{H}_{22}\text{O}_{11}$)
 - d. calcium sulfide (CaS)
56. Not all element names come from English or Latin words. The symbol for tungsten is W from the German word *wolfram*. The symbol for mercury is Hg from the Greek word *hydragyrum*. Use the symbols W and Hg to explain the system of symbols for elements.
- *57. What does the formula H_2O tell you about the composition of water?

58. Look up the word *periodic* in the dictionary. Propose a reason for the naming of the periodic table.

2.4 Chemical Reactions

59. Use the word equation below to explain how a chemical change differs from a physical change.



- *60. Classify each of the following as a physical or chemical change. For any chemical change, list at least one clue to support your answer.
- A copper wire is bent.
 - Charcoal burns in a grill.
 - Bread dough rises when yeast is added.
 - Sugar dissolves in water.
61. Which type of property cannot be observed without changing the composition of a substance?
- *62. When ammonium nitrate (NH_4NO_3) explodes, the products are nitrogen, oxygen, and water. When 40 grams of ammonium nitrate explode, 14 grams of nitrogen and 8 grams of oxygen form. How many grams of water form?

Understand Concepts

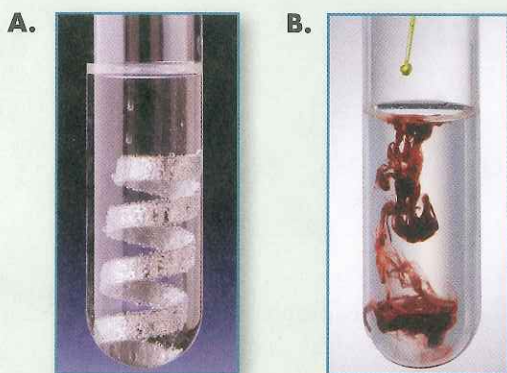
Use the data table to answer Questions 63–66.

Substance	Color	Melting point ($^{\circ}\text{C}$)	Boiling point ($^{\circ}\text{C}$)
Bromine	Red-brown	-7	59
Chlorine	Green-yellow	-101	-34
Ethanol	Colorless	-117	78
Mercury	Silvery-white	-39	357
Neon	Colorless	-249	-246
Sulfur	Yellow	115	445
Water	Colorless	0	100

63. Which colorless substance is a liquid at -30°C ?
64. Which colorless substance is a gas at 60°C ?
65. Which substance is a solid at 7°C ?
- *66. As the temperature rises, which solid will melt before mercury boils?

- *67. Explain why mass cannot be used as a property to identify a sample of matter.
68. Is malleability an extensive property or an intensive property? Explain.
69. The state of a substance can change when the substance is heated or cooled. So what does it mean to say that a certain substance is a solid, liquid, or gas?
- *70. Use the arrangement of particles in solids and gases to explain why solids are not as easy to compress as gases.
71. You are standing in a kitchen and then in the middle of a park. When you view your surroundings in each location, do you see mostly elements, compounds, or mixtures?
72. Identify each of the following items as a mixture or compound. Classify the mixtures as homogeneous or heterogeneous.
- raw egg
 - ice
 - gasoline
 - blood
73. Classify the following properties of the element silicon as chemical or physical properties:
- blue-gray color
 - brittle
 - doesn't dissolve in water
 - melts at 1410°C
 - reacts vigorously with fluorine
74. How are the items in each of the following pairs similar? How are they different?
- copper and silver
 - distilled water and salt water
 - table sugar and table salt
75. Identify each of the following as an element, compound or mixture.
- iron
 - distilled water
 - laundry detergent
 - sulfur
 - chicken broth
 - sodium fluoride

- *76. Describe clues you might observe during the following events that could support the conclusion that a chemical change is occurring.
- An antacid tablet is dropped into water.
 - A ring of scum forms around a bathtub.
 - Iron rusts.
 - A firecracker explodes.
 - Bubbles form when hydrogen peroxide is poured onto an open wound.
 - A hamburger cooks.
77. In photograph A, a coil of zinc metal is in a solution of sulfuric acid. In photograph B, a yellow solution of sodium chromate is being added to a colorless solution of silver nitrate. What clues in the photographs indicate that a chemical change is probably occurring?

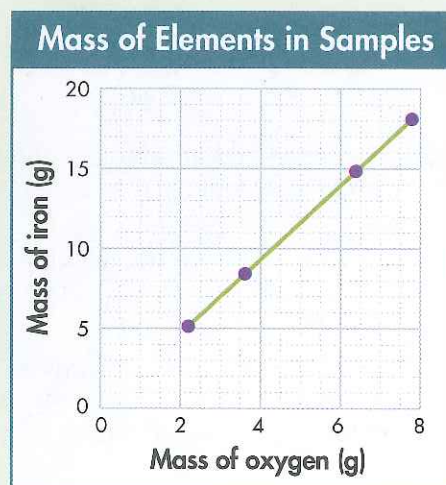


78. Classify each of the following as a chemical change or a physical change.
- Plastic drink bottles are burned in an incinerator to generate electricity.
 - Digesting a cereal bar.
 - Water in a rain puddle evaporates.
 - Slicing a tomato for a sandwich.
 - Plastic drink bottles are recycled to make fiberfill for ski jackets.
79. Explain why the production of a gas does not always mean that a chemical reaction has occurred.
- *80. The wax seems to disappear as a candle burns. How can the law of conservation of mass apply to this reaction?

Think Critically

- *81. **Apply Concepts** Devise a way to separate sand from a mixture of charcoal, sand, sugar, and water.

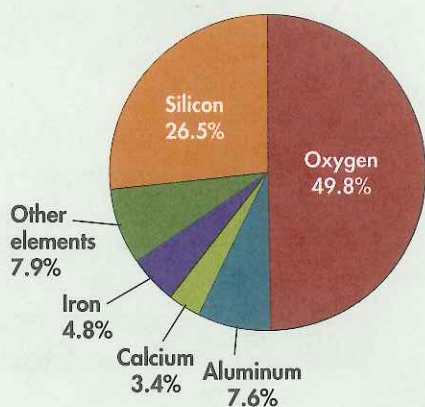
82. **Sequence** Assume that water, mercury, and gallium are all at 40°C . As the temperature drops, which substance will freeze first? Which will be the last to freeze?
83. **Apply Concepts** A change in odor can also be a clue that a chemical change has occurred. Describe at least one situation in which you might be likely to detect such a change in odor in a kitchen.
84. **Explain** Explain why this statement is false. "Because there is no change in composition during a physical change, the appearance of the substance will not change."
- *85. **Interpret Graphs** The mass of the elements iron and oxygen in four samples of a rust-colored substance was measured in grams (g). The amount of iron and oxygen in each sample is shown on the graph.



- Do you think all four samples are the same compound? Explain.
 - Another sample of similar material was found to contain 9.9 grams of iron and 3.4 grams of oxygen. Is this sample the same substance as the other four samples? Explain.
86. **Explain** When powdered iron is left exposed to the air, it rusts. Explain why the mass of the rust is greater than the mass of the powdered iron.
87. **Explain** Discuss the statement "A gas requires a container, but a solid is its own container."

Enrichment

- *88. **Interpret Graphs** Five elements make up 98% of the mass of the human body. These elements are oxygen (61%), carbon (23%), hydrogen (10.0%), nitrogen (2.6%), and calcium (1.4%). Compare these data with those in the pie graph below, which shows the five most abundant elements by mass in Earth's crust, oceans, and atmosphere.



- Which elements are abundant both in the human body and Earth's crust, oceans, and atmosphere?
 - Which elements are abundant in Earth's crust, oceans, and atmosphere, but not in the human body?
 - Would you expect the compounds found in the human body to be the same as or different from those found in rocks, seawater, and air? Use the data to explain your answer.
89. **Evaluate** Each day you encounter some chemical changes that are helpful and some that are harmful to humans or the environment. Cite three examples of each type. For each example, list the clues that identified the change as a chemical change.
90. **Interpret Tables** Use Table 2.1 on page 35 to answer this question.
- Which substances in the table are in the liquid state at 125°C?
 - Use the physical properties of one of these substances to explain how you figured out the answer to Question 90a.
 - The substances in the table are listed in order of increasing melting point. Propose another way that these data could be arranged.

Write About Science

91. **Explain** Write a paragraph in support of this statement: "Dry tea is a mixture, not a substance." Include at least two pieces of evidence to support your argument.
92. **Explain** Lavoisier proposed the law of conservation of mass in 1789. Write a paragraph describing, in general, what Lavoisier must have done before he proposed this law. Use what you have learned about the scientific method.
93. **Connect to the BIG IDEA** Compare elements and compounds by saying how they are alike. Contrast elements and compounds by describing how they are different.

CHEMYSTERY

Which One Is Not Like the Others?



The eruption of geysers in Yellowstone National Park is caused by a physical change. Underground water is heated to temperatures hot enough to turn the water into steam. This steam causes an increase in pressure underground. In the cases of geysers, the steam is at first unable to escape. But, when the pressure reaches a critical level, an eruption occurs, producing the geyser.

The shaping of valleys by melt-refreeze cycles is also a physical change. The melting and refreezing of water is a physical change, and as the earth underneath the glacier is broken apart and moved, this is also a physical change.

The changing of the color of leaves is a chemical change. As the temperature and hours of sunlight change in the fall, chemical changes occur. Therefore, leaves changing color, a chemical change, is not like the physical changes of geysers erupting or glaciers moving.

94. **Identify** Are the physical changes in the mystery reversible or irreversible physical changes? Explain your answer.
95. **Connect to the BIG IDEA** Why would it be important for rangers at national parks to have knowledge of physical and chemical changes?

Standardized Test Prep

Select the choice that best answers each question or completes each statement.

- Which of the following is not a chemical change?
 - paper being shredded
 - steel rusting
 - charcoal burning
 - a newspaper yellowing in the sun
- Which phrase best describes an apple?
 - heterogeneous mixture
 - homogeneous compound
 - heterogeneous substance
 - homogeneous mixture
- Which element is paired with the wrong symbol?
 - sulfur, S
 - potassium, P
 - nitrogen, N
 - calcium, Ca
- Which of these properties could not be used to distinguish between table salt and table sugar?
 - boiling point
 - melting point
 - density
 - color
- The state of matter characterized by a definite volume and an indefinite shape is a
 - solid.
 - liquid.
 - mixture.
 - gas.

The lettered choices below refer to Questions 6–9. A lettered choice may be used once, more than once, or not at all.

- compound
- heterogeneous mixture
- element
- homogeneous mixture

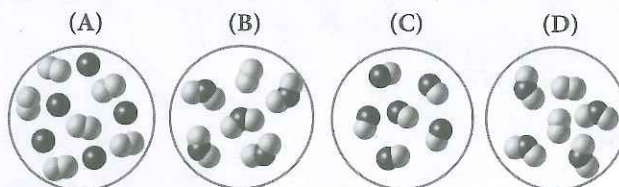
Which description correctly identifies each of the following materials?

- air
- carbon monoxide
- zinc
- mushroom pizza

Tips for Success

Using Models To answer some test questions, you will be asked to use visual models. At first the models may look very similar. Decide which information will help you answer the question. The number of particles, their colors, or their shapes may or may not be important.

Use the atomic windows to answer Question 10.



- The species in window A react. Use the law of conservation of mass to determine which window best represents the reaction products.

Use the data table to answer Questions 11–14.

Mass of magnesium (g)	Mass of oxygen (g)	Mass of magnesium oxide (g)
5.0	3.3	8.3
6.5	(a)	10.8
13.6	9.0	(b)
(c)	12.5	31.5

- Magnesium metal burns vigorously in oxygen to produce the compound magnesium oxide. Use the law of conservation of mass to identify the masses labeled (a), (b), and (c) in the table.
- Use the data in the completed table to construct a graph with mass of magnesium on the x -axis and mass of magnesium oxide on the y -axis.
- How many grams of magnesium oxide form when 8.0 g of magnesium are burned?
- How many grams of magnesium and oxygen react to form 20.0 g of magnesium oxide?

If You Have Trouble With . . .

Question	1	2	3	4	5	6	7	8	9	10	11	12	13	14
See Lesson	2.4	2.2	2.3	2.1	2.1	2.3	2.3	2.3	2.3	2.4	2.4	2.4	2.4	2.4