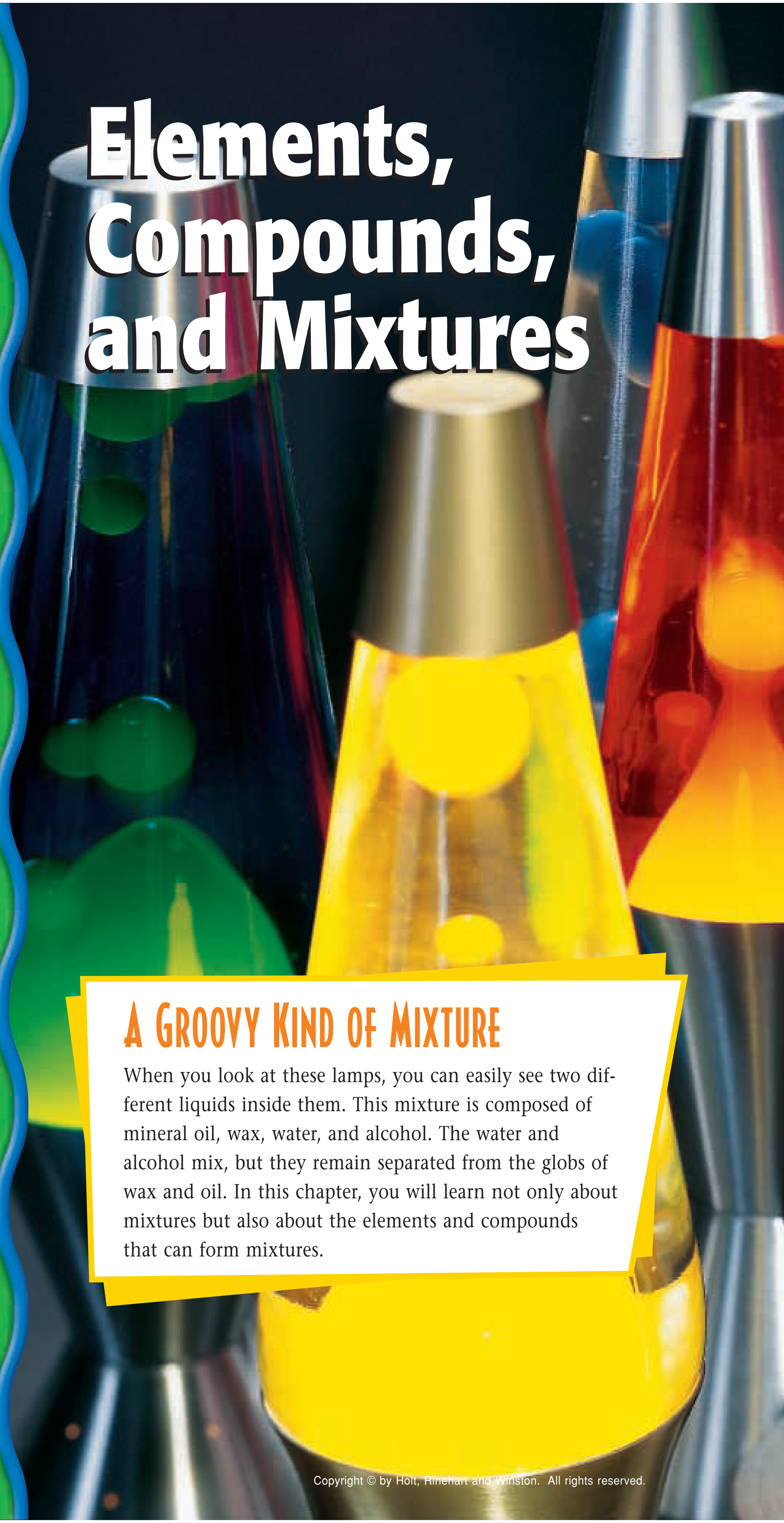
CHAPTER 4

Elements, Compounds, and Mixtures



Sections

A Groovy Kind of Mixture

When you look at these lamps, you can easily see two different liquids inside them. This mixture is composed of mineral oil, wax, water, and alcohol. The water and alcohol mix, but they remain separated from the globs of wax and oil. In this chapter, you will learn not only about mixtures but also about the elements and compounds that can form mixtures.

Pre-Reading Questions

1. What is an element?
2. What is a compound? How are compounds and mixtures different?
3. What are the components of a solution called?

MYSTERY MIXTURE

In this activity, you will separate the different dyes found in an ink mixture.

Procedure

1. Tear a strip of paper (about 3 cm $\times$ 15 cm) from a **coffee filter.** Wrap one end of the strip around a **pencil** so that the other end will just touch the bottom of a **clear plastic cup.** Use **tape** to attach the paper to the pencil.
2. Take the paper out of the cup. Using a **water-soluble black marker,** make a small dot in the center of the strip about 2 cm from the bottom.
3. Pour **water** in the cup to a depth of 1 cm. Carefully lower the paper into the cup. Be sure the dot is not under water.
4. Remove the paper when the water is 1 cm from the top. Record your observations in your ScienceLog.

Analysis

5. Infer what happened as the filter paper soaked up the water.
6. Which colors were mixed to make your black ink?
7. Compare your results with those of your classmates. Record your observations.
8. Infer whether the process used to make the ink involved a physical or chemical change. Explain.

Section 1

Elements

Terms to Learn

element
pure substance
metals
nonmetals
metalloids

What You'll Do

- Describe pure substances.
- Describe the characteristics of elements, and give examples.
- Explain how elements can be identified.
- Classify elements according to their properties.

Imagine you are working as a lab technician for the Break-It-Down Corporation. Your job is to break down materials into the simplest substances you can obtain. One day a material seems particularly difficult to break down. You crush and grind it. You notice that the resulting pieces are smaller, but they are still the same material. You try other physical changes, including melting, boiling, and filtering it, but the material does not change into anything simpler.

Next you try some chemical changes. You pass an electric current through the material but it still does not become any simpler. After recording your observations, you analyze the results of your tests. You then draw a conclusion: the substance must be an element. An **element** is a pure substance that cannot be separated into simpler substances by physical or chemical means, as shown in **Figure 1.**

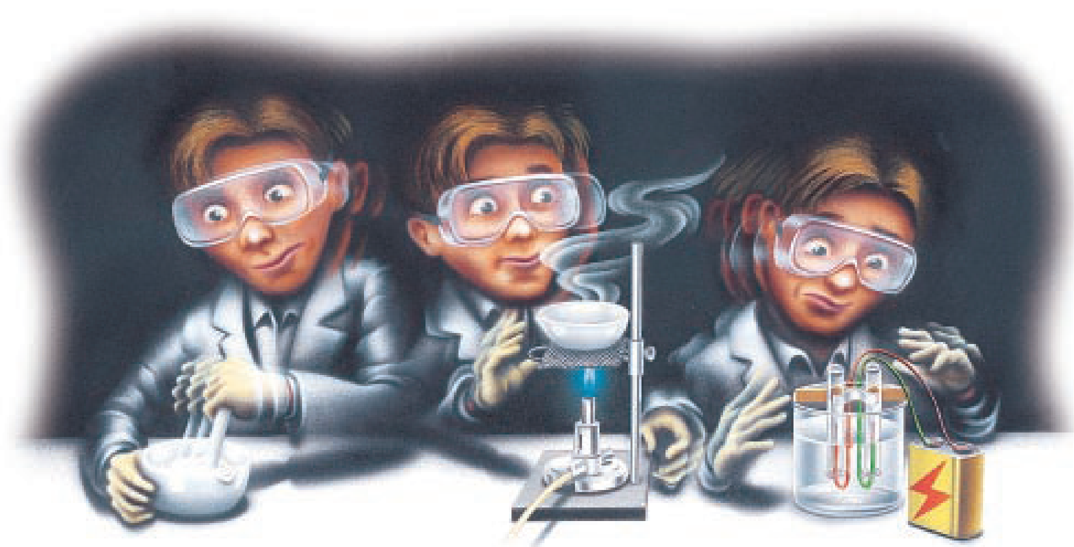


Figure 1 *No matter what kind of physical or chemical change you attempt, an element cannot be changed into a simpler substance!*

Figure 2 *The atoms of the element iron are alike whether they are in a meteorite or in a common iron skillet.*

An Element Has Only One Type of Particle

A **pure substance** is a substance in which there is only one type of particle. Because elements are pure substances, each element contains only one type of particle. For example, every particle (atom) in a 5 g nugget of the element gold is like every other particle of gold. The particles of a pure substance are alike no matter where that substance is found, as shown in **Figure 2.** Although a meteorite might travel more than 400 million kilometers (about 248 million miles) to reach Earth, the particles of iron in a meteorite are identical to the particles of iron in objects around your home!

Every Element Has a Unique Set of Properties

Each element has a unique set of properties that allows you to identify it. For example, each element has its own *characteristic properties*. These properties do not depend on the amount of material present in a sample of the element. Characteristic properties include some physical properties, such as boiling point, melting point, and density, as well as chemical properties, such as reactivity with acid. The elements helium and krypton are unreactive gases. However, the density (mass per unit volume) of helium is less than the density of air. Therefore, a helium-filled balloon will float up if it is released. Krypton is more dense than air, so a krypton-filled balloon will sink to the ground if it is released.

Identifying Elements by Their Properties Look at the elements cobalt, iron, and nickel, shown in **Figure 3.** Even though these three elements have some similar properties, each can be identified by its unique set of properties.

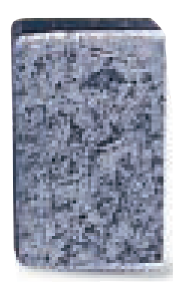
Notice that the physical properties for the elements in Figure 3 include melting point and density. Other physical properties, such as color, hardness, and texture, could be added to the list. Also, depending on the elements being identified, other chemical properties might be useful. For example, some elements, such as hydrogen and carbon, are flammable. Other elements, such as sodium, react immediately with oxygen. Still other elements, such as zinc, are reactive with acid.

Cobalt

Melting point is 1,495°C.
Density is 8.9 g/cm^3.
Conducts electric current and thermal energy.
Unreactive with oxygen in the air.

Iron

Melting point is 1,535°C.
Density is 7.9 g/cm^3.
Conducts electric current and thermal energy.
Combines slowly with oxygen in the air to form rust.



Nickel

Melting point is 1,455°C.
Density is 8.9 g/cm^3.
Conducts electric current and thermal energy.
Unreactive with oxygen in the air.

Figure 3 *Like all other elements, cobalt, iron, and nickel can be identified by their unique combination of properties.*

Elements Are Classified by Their Properties

Consider how many different breeds of dogs there are. Consider also how you tell one breed from another. Most often you can tell just by their appearance, or what might be called physical properties. **Figure 4** shows several breeds of dogs, which all happen to be terriers. Many terriers are fairly small in size and have short hair. Although not all terriers are exactly alike, they share enough common properties to be classified in the same group.

Figure 4 *Even though these dogs are different breeds, they have enough in common to be classified as terriers.*

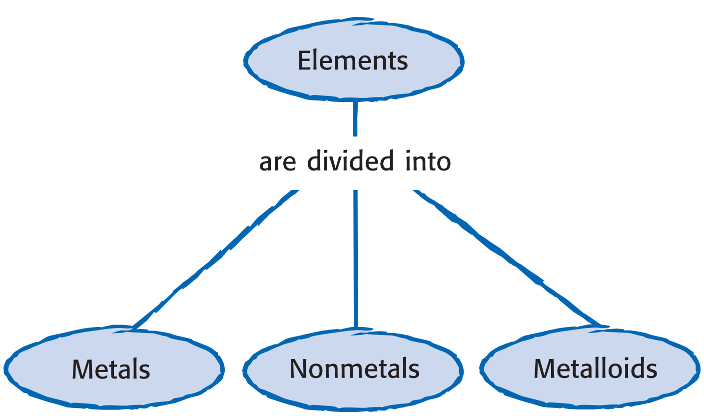
Elements Are Grouped into Categories

Elements are classified into groups according to their shared properties. Recall the elements iron, nickel, and cobalt. All three are shiny, and all three conduct thermal energy and electric current. Using these shared properties, scientists have grouped these three elements, along with other similar elements, into one large group called metals. Metals are not all exactly alike, but they do have some properties in common.

If You Know the Category, You Know the Properties If you have ever browsed at a music store, you know that the CDs are categorized by type of music. If you like rock-and-roll, you would go to the rock-and-roll section. You might not recognize a particular CD, but you know that it must have the characteristics of rock-and-roll for it to be in this section.

Likewise, you can predict some of the properties of an unfamiliar element by knowing the category to which it belongs. As shown in the concept map in **Figure 5,** elements are classified into three categories—metals, nonmetals, and metalloids. Cobalt, iron, and nickel are classified as metals. If you know that a particular element is a metal, you know that it shares certain properties with iron, nickel, and cobalt. The chart on the next page shows examples of each category and describes the properties that identify elements in each category.

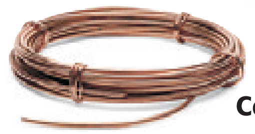
Figure 5 *Elements are divided into three categories: metals, nonmetals, and metalloids.*



The Three Major Categories of Elements

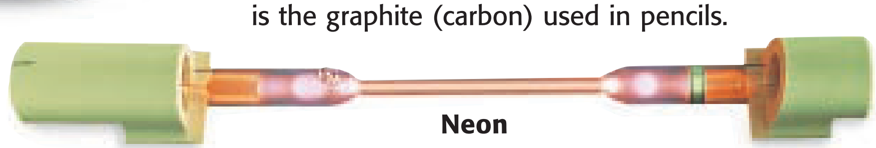
Metals

Metals are elements that are shiny and are good conductors of thermal energy and electric current. They are *malleable* (they can be hammered into thin sheets) and *ductile* (they can be drawn into thin wires). Iron has many uses in building and automobile construction. Copper is used in wires and coins.



Nonmetals

Nonmetals are elements that are dull (not shiny) and that are poor conductors of thermal energy and electric current. Solid nonmetals tend to be brittle and unmalleable. Few familiar objects are made of only nonmetals. The neon used in lights is a nonmetal, as is the graphite (carbon) used in pencils.



Metalloids

Metalloids, also called semiconductors, are elements that have properties of both metals and nonmetals. Some metalloids are shiny, while others are dull. Metalloids are somewhat malleable and ductile. Some metalloids conduct thermal energy and electric current well. Silicon is used to make computer chips. However, other elements must be added to silicon to make a working chip.

REVIEW

1. What is a pure substance?
2. List three properties that can be used to classify elements.
3. **Applying Concepts** Which category of element would be the least appropriate choice for making a container that can be dropped without shattering? Explain your reasoning.

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Section 2

Compounds

Terms to Learn

compound

What You'll Do

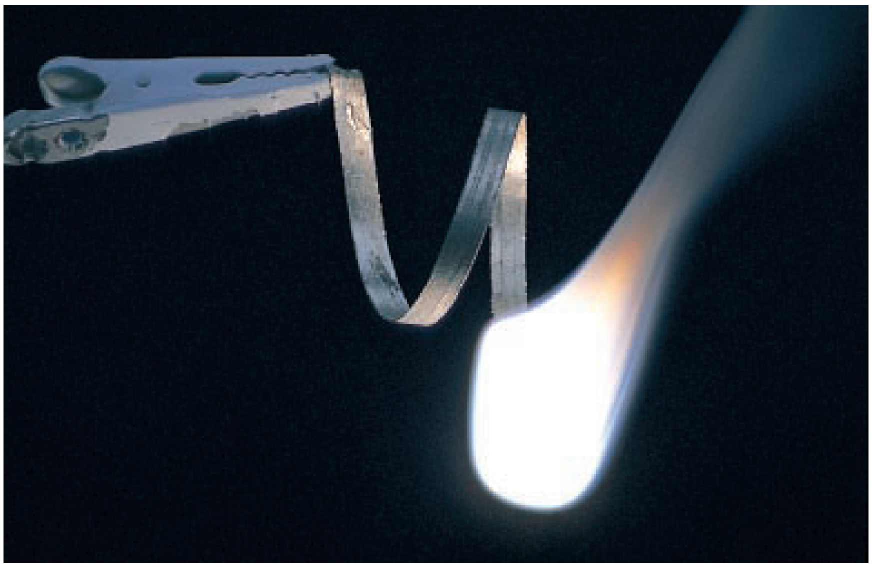
- Describe the properties of compounds.
- Identify the differences between an element and a compound.
- Give examples of common compounds.

Most elements take part in chemical changes fairly easily, so few elements are found alone in nature. Instead, most elements are found combined with other elements as compounds.

A **compound** is a pure substance composed of two or more elements that are chemically combined. In a compound, a particle is formed when atoms of two or more elements join together. In order for elements to combine, they must *react,* or undergo a chemical change, with one another. In **Figure 6,** you see magnesium reacting with oxygen to form a compound called magnesium oxide. The compound is a new pure substance that is different from the elements that reacted to form it. Most substances you encounter every day are compounds. The table at left lists some familiar examples.

Familiar Compounds
table salt— sodium and chlorine
water— hydrogen and oxygen
sugar— carbon, hydrogen, and oxygen
carbon dioxide— carbon and oxygen
baking soda— sodium, hydrogen, carbon, and oxygen

Figure 6 *As magnesium burns, it reacts with oxygen and forms the compound magnesium oxide.*



Elements Combine in a Definite Ratio to Form a Compound

Compounds are not random combinations of elements. When a compound forms, the elements join in a specific ratio according to their masses. For example, the ratio of the mass of hydrogen to the mass of oxygen in water is always the same—1 g of hydrogen to 8 g of oxygen. This mass ratio can be written as 1:8 or as the fraction 1/8. Every sample of water has this 1:8 mass ratio of hydrogen to oxygen. If a sample of a compound has a different mass ratio of hydrogen to oxygen, the compound cannot be water.

Every Compound Has a Unique Set of Properties

Each compound has a unique set of properties that allows you to distinguish it from other compounds. Like elements, each compound has its own physical properties, such as boiling point, melting point, density, and color. Compounds can also be identified by their different chemical properties. Some compounds, such as the calcium carbonate found in chalk, react with acid. Others, such as hydrogen peroxide, react when exposed to light. You can see how chemical properties can be used to identify compounds in the QuickLab at right.

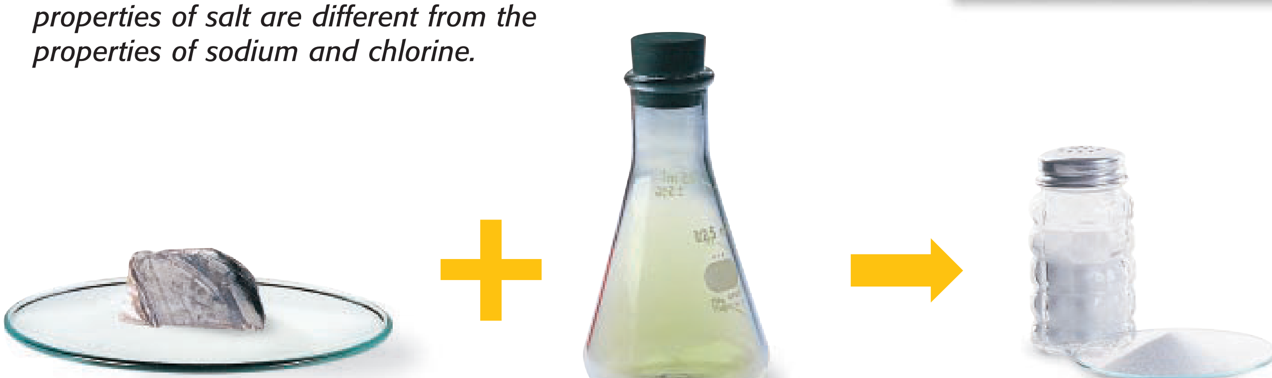
A compound has different properties from the elements that form it. Did you know that ordinary table salt is a compound made from two very dangerous elements? Table salt—sodium chloride—consists of sodium (which reacts violently with water) and chlorine (which is poisonous). Together, however, these elements form a harmless compound with unique properties. Take a look at **Figure 7.** Because a compound has different properties from the elements that react to form it, sodium chloride is safe to eat and dissolves (without exploding!) in water.

QuickLab

Compound Confusion

1. Measure 4 g (1 tsp) of **compound A,** and place it in a **clear plastic cup.**
2. Measure 4 g (1 tsp) of **compound B,** and place it in a **second clear plastic cup.**
3. Observe the color and texture of each compound. Record your observations.
4. Add 5 mL (1 tsp) of **vinegar** to each cup. Record your observations.
5. Baking soda reacts with vinegar, while powdered sugar does not. Which of these compounds is compound A, and which is compound B?

Figure 7 *Table salt is formed when the elements sodium and chlorine join. The properties of salt are different from the properties of sodium and chlorine.*



Sodium is a soft, silvery white metal that reacts violently with water.

Chlorine is a poisonous, greenish yellow gas.

Sodium chloride, or table salt, is a white solid that dissolves easily in water and is safe to eat.

Self-Check

Do the properties of pure water from a glacier and from a desert oasis differ? *(See page 724 to check your answer.)*

Compounds Can Be Broken Down into Simpler Substances

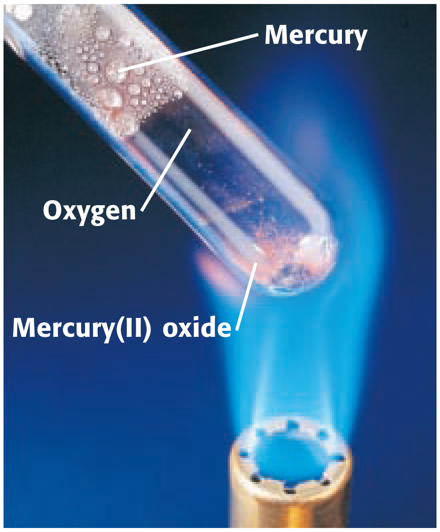


Figure 8 *Heating mercury(II) oxide causes a chemical change that separates it into the elements mercury and oxygen.*

Some compounds can be broken down into elements through chemical changes. Look at **Figure 8.** When the compound mercury(II) oxide is heated, it breaks down into the elements mercury and oxygen. Likewise, if an electric current is passed through melted table salt, the elements sodium and chlorine are produced.

Other compounds undergo chemical changes to form simpler compounds. These compounds can be broken down into elements through additional chemical changes. For example, carbonic acid is a compound that helps to give carbonated beverages their "fizz," as shown in **Figure 9.** The carbon dioxide and water that are formed can be further broken down into the elements carbon, oxygen, and hydrogen through additional chemical changes.

Figure 9 *Opening a carbonated drink can be messy as carbonic acid breaks down into two simpler compounds–carbon dioxide and water.*

Physics CONNECTION

The process of using electric current to break compounds into simpler compounds and elements is known as electrolysis. Electrolysis can be used to separate water into hydrogen and oxygen. The elements aluminum and copper and the compound hydrogen peroxide are important industrial products obtained through electrolysis.

Compounds Cannot Be Broken Down by Physical Changes

The only way to break down a compound is through a chemical change. If you pour water through a filter, the water will pass through the filter unchanged. Filtration is a physical change, so it cannot be used to break down a compound. Likewise, a compound cannot be broken down by being ground into a powder or by any other physical process.

Compounds in Your World

You are always surrounded by compounds. Compounds make up the food you eat, the school supplies you use, the clothes you wear—even you!

Compounds in Nature Proteins are compounds found in all living things. The element nitrogen is needed to make proteins. **Figure 10** shows how some plants get the nitrogen they need. Other plants use nitrogen compounds that are in the soil. Animals get the nitrogen they need by eating plants or by eating animals that have eaten plants. As an animal digests food, the proteins in the food are broken down into smaller compounds that the animal's cells can use.

Another compound that plays an important role in life is carbon dioxide. You exhale carbon dioxide that was made in your body. Plants take in carbon dioxide and use it to make other compounds, including sugar.

Figure 10 *The bumps on the roots of this pea plant are home to bacteria that form compounds from atmospheric nitrogen. The pea plant makes proteins from these compounds.*

Compounds in Industry The element nitrogen is combined with the element hydrogen to form a compound called ammonia. Ammonia is manufactured for use in fertilizers. Plants can use ammonia as a source of nitrogen for their proteins. Other manufactured compounds are used in medicines, food preservatives, and synthetic fabrics.

The compounds found in nature are usually not the raw materials needed by industry. Often, these compounds must be broken down to provide elements used as raw material. For example, the element aluminum, used in cans, airplanes, and building materials, is not found alone in nature. It is produced by breaking down the compound aluminum oxide.

REVIEW

1. What is a compound?
2. What type of change is needed to break down a compound?
3. **Analyzing Ideas** A jar contains samples of the elements carbon and oxygen. Does the jar contain a compound? Explain.

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Section 3

Mixtures

Terms to Learn

mixture
solution
solute
solvent
concentration
solubility
suspension
colloid

What You'll Do

- Describe the properties of mixtures.
- Describe methods of separating the components of a mixture.
- Analyze a solution in terms of its solute, solvent, and concentration.
- Compare the properties of solutions, suspensions, and colloids.

Have you ever made your own pizza? You roll out the dough, add a layer of tomato sauce, then add toppings like green peppers, mushrooms, and olives—maybe even some pepperoni! Sprinkle cheese on top, and you're ready to bake. You have just created not only a pizza but also a mixture—and a delicious one at that!

Properties of Mixtures

All mixtures—even pizza—share certain properties. A **mixture** is a combination of two or more substances that are not chemically combined. Two or more materials together form a mixture if they do not react to form a compound. For example, cheese and tomato sauce do not react when they are used to make a pizza.

Figure 11 *Colorless quartz, pink feldspar, and black mica make up the mixture granite.*

Substances in a Mixture Retain Their Identity Because no chemical change occurs, each substance in a mixture has the same chemical makeup it had before the mixture formed. That is, each substance in a mixture keeps its identity. In some mixtures, such as the pizza above or the piece of granite shown in **Figure 11,** you can even see the individual components. In other mixtures, such as salt water, you cannot see all the components.

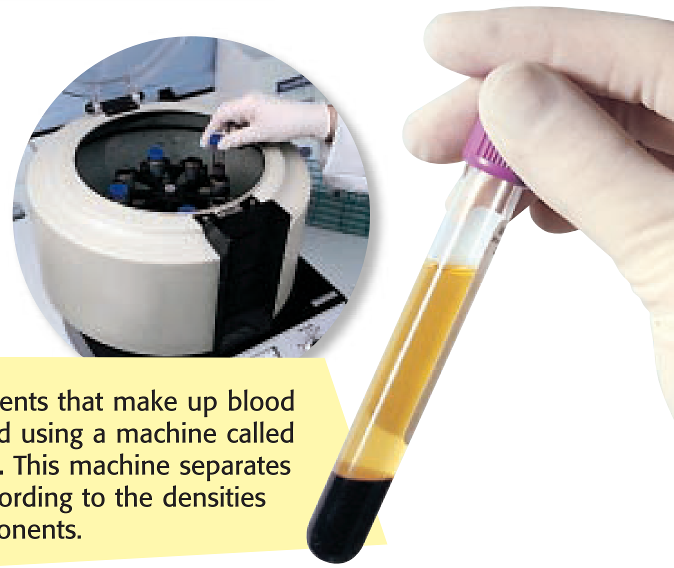
Mixtures Can Be Physically Separated If you don't like mushrooms on your pizza, you can pick them off. This is a physical change of the mixture. The identities of the substances did not change. In contrast, compounds can be broken down only through chemical changes.

Not all mixtures are as easy to separate as a pizza. You cannot simply pick salt out of a saltwater mixture, but you can separate the salt from the water by heating the mixture. When the water changes from a liquid to a gas, the salt remains behind. Several common techniques for separating mixtures are shown on the following page.

Common Techniques for Separating Mixtures

Distillation is a process that separates a mixture based on the boiling points of the components. Here you see pure water being distilled from a saltwater mixture. In addition to water purification, distillation is used to separate crude oil into its components, such as gasoline and kerosene.

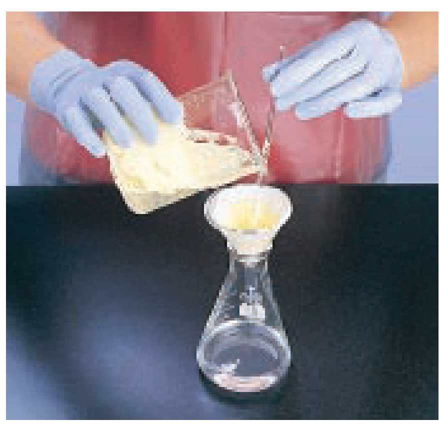
A **magnet** can be used to separate a mixture of the elements iron and aluminum. Iron is attracted to the magnet, but aluminum is not.



The components that make up blood are separated using a machine called a **centrifuge.** This machine separates mixtures according to the densities of the components.

A mixture of the compound sodium chloride (table salt) with the element sulfur requires more than one separation step.

1 The **first step** is to mix them with another compound—water. Salt dissolves in water, but sulfur does not.



2 In the **second step,** the mixture is poured through a filter. The filter traps the solid sulfur.

3 In the **third step,** the sodium chloride is separated from the water by simply evaporating the water.

Mixtures vs. Compounds

Mixtures	Compounds
Components are elements, compounds, or both	Components are elements
Components keep their original properties	Components lose their original properties
Separated by physical means	Separated by chemical means
Formed using any ratio of components	Formed using a set mass ratio of components

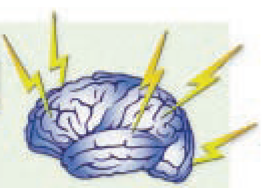
The Components of a Mixture Do Not Have a Definite Ratio Recall that a compound has a specific mass ratio of the elements that form it. Unlike compounds, the components of a mixture do not need to be combined in a definite ratio. For example, granite that has a greater amount of feldspar than mica or quartz appears to have a pink color. Granite that has a greater amount of mica than feldspar or quartz appears black. Regardless of which ratio is present, this combination of materials is always a mixture—and it is always called granite.

Air is a mixture composed mostly of nitrogen and oxygen, with smaller amounts of other gases, such as carbon dioxide and water vapor. Some days the air has more water vapor, or is more humid, than on other days. But regardless of the ratio of the components, air is still a mixture.The chart at left summarizes the differences between mixtures and compounds.

REVIEW

1. What is a mixture?
2. Is a mixture separated by physical or chemical changes?
3. **Applying Concepts** Suggest a procedure to separate iron filings from sawdust. Explain why this procedure works.

BRAIN FOOD



Many substances are soluble in water, including salt, sugar, alcohol, and oxygen. Water does not dissolve everything, but it dissolves so many different solutes that it is often called the universal solvent.

Solutions

A **solution** is a mixture that appears to be a single substance but is composed of particles of two or more substances that are distributed evenly amongst each other. Solutions are often described as *homogeneous mixtures* because they have the same appearance and properties throughout the mixture.

The process in which particles of substances separate and spread evenly throughout a mixture is known as *dissolving*. In solutions, the **solute** is the substance that is dissolved, and the **solvent** is the substance in which the solute is dissolved. A solute is *soluble,* or able to dissolve, in the solvent. A substance that is *insoluble,* or unable to dissolve, forms a mixture that is not homogeneous and therefore is not a solution.

Salt water is a solution. Salt is soluble in water, meaning that salt dissolves in water. Therefore, salt is the solute and water is the solvent. When two liquids or two gases form a solution, the substance with the greater volume is the solvent.

You may think of solutions as being liquids. And, in fact, tap water, soft drinks, gasoline, and many cleaning supplies are liquid solutions. However, solutions may also be gases, such as air, and solids, such as steel. *Alloys* are solid solutions of metals or nonmetals dissolved in metals. Brass is an alloy of the metal zinc dissolved in copper. Steel, including that used to build the *Titanic,* is an alloy made of the nonmetal carbon and other elements dissolved in iron. Look at the chart below for examples of the different states of matter used as solutes and solvents in solutions.

Self-Check

Yellow gold is an alloy made from equal parts copper and silver combined with a greater amount of gold. Identify each component of yellow gold as a solute or solvent. *(See page 724 to check your answer.)*

Examples of Different States in Solutions

Gas in gas	Dry air (oxygen in nitrogen)
Gas in liquid	Soft drinks (carbon dioxide in water)
Liquid in liquid	Antifreeze (alcohol in water)
Solid in liquid	Salt water (salt in water)
Solid in solid	Brass (zinc in copper)

Particles in Solutions Are Extremely Small The particles in solutions are so small that they never settle out, nor can they be filtered out of these mixtures. In fact, the particles are so small, they don't even scatter light. Look at **Figure 12** and see for yourself. The jar on the left contains a solution of sodium chloride in water. The jar on the right contains a mixture of gelatin in water.

Figure 12 *Both of these jars contain mixtures. The mixture in the jar on the left, however, is a solution. The particles in solutions are so small they don't scatter light. Therefore, you can't see the path of light through it.*

MATHBREAK

Calculating Concentration

Many solutions are colorless. Therefore, you cannot always compare the concentrations of solutions by looking at the color—you have to compare the actual calculated concentrations. One way to calculate the concentration of a liquid solution is to divide the grams of solute by the milliliters of solvent. For example, the concentration of a solution in which 35 g of salt is dissolved in 175 mL of water is

$$\frac{35\text{ g salt}}{175\text{ mL water}} = 0.2\text{ g/mL}$$

Now It's Your Turn

Calculate the concentrations of each solution below. Solution A has 55 g of sugar dissolved in 500 mL of water. Solution B has 36 g of sugar dissolved in 144 mL of water. Which solution is the more dilute one? Which is the more concentrated?

Concentration: How Much Solute Is Dissolved? A measure of the amount of solute dissolved in a solvent is **concentration.** Concentration can be expressed in grams of solute per milliliter of solvent. Knowing the exact concentration of a solution is very important in chemistry and medicine because using the wrong concentration can be dangerous.

Solutions can be described as being *concentrated* or *dilute*. Look at **Figure 13.** Both solutions have the same amount of solvent, but the solution on the left contains less solute than the solution on the right. The solution on the left is dilute while the solution on the right is concentrated. Keep in mind that the terms *concentrated* and *dilute* do not specify the amount of solute that is actually dissolved. Try your hand at calculating concentration and describing solutions as concentrated or dilute in the MathBreak at left.

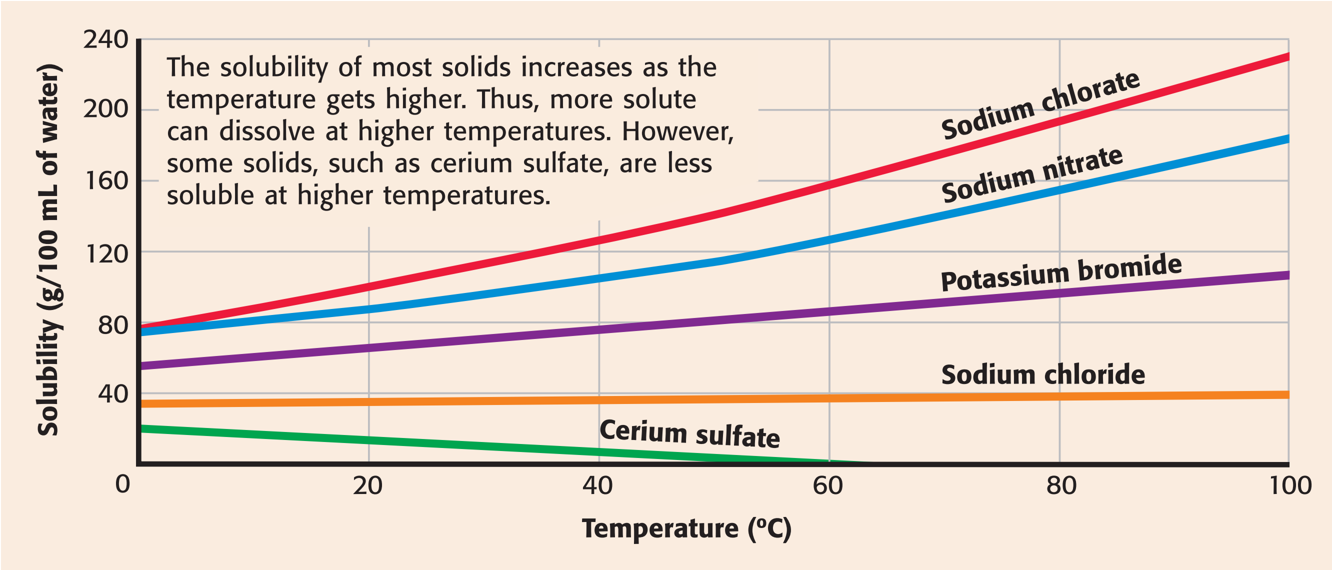
Figure 13 *The dilute solution on the left contains less solute than the concentrated solution on the right.*

A solution that contains all the solute it can hold at a given temperature is said to be *saturated*. An *unsaturated* solution contains less solute than it can hold at a given temperature. More solute can dissolve in an unsaturated solution.

Solubility: How Much Solute Can Dissolve? If you add too much sugar to a glass of lemonade, not all of the sugar can dissolve. Some of the sugar collects on the bottom of the glass. To determine the maximum amount of sugar that can dissolve, you would need to know the solubility of sugar. The **solubility** of a solute is the amount of solute needed to make a saturated solution using a given amount of solvent at a certain temperature. Solubility is usually expressed in grams of solute per 100 mL of solvent. **Figure 14** on the next page shows the solubility of several different substances in water at different temperatures.

Smelly solutions? Follow your nose and learn more on page 102.

Figure 14 Solubility of Different Substances



Unlike the solubility of most solids in liquids, the solubility of gases in liquids decreases as the temperature is raised. Bubbles of gas appear in hot water long before the water begins to boil. The gases that are dissolved in the water cannot remain dissolved as the temperature increases because the solubility of the gases is lower at higher temperatures.

What Affects How Quickly Solids Dissolve in Liquids?

Many familiar solutions are formed when a solid solute is dissolved in water. Several factors affect how fast the solid will dissolve. Look at **Figure 15** to see three methods used to make a solute dissolve faster. You can see why you will enjoy a glass of lemonade sooner if you stir granulated sugar into the lemonade before adding ice!

Figure 15 *Mixing, heating, and crushing iron(III) chloride increase the speed at which it will dissolve.*

Mixing by stirring or shaking causes the solute particles to separate from one another and spread out more quickly among the solvent particles.

Heating causes particles to move more quickly. The solvent particles can separate the solute particles and spread them out more quickly.

Crushing the solute increases the amount of contact between the solute and the solvent. The particles of solute mix with the solvent more quickly.

Biology CONNECTION

Blood is a suspension. The suspended particles, mainly red blood cells, white blood cells, and platelets, are actually suspended in a solution called plasma. Plasma is 90 percent water and 10 percent dissolved solutes, including sugar, vitamins, and proteins.

Suspensions

When you shake up a snow globe, you are mixing the solid snow particles with the clear liquid. When you stop shaking the globe, the snow particles settle to the bottom of the globe. This mixture is called a suspension. A **suspension** is a mixture in which particles of a material are dispersed throughout a liquid or gas but are large enough that they settle out. The particles are insoluble, so they do not dissolve in the liquid or gas. Suspensions are often described as *heterogeneous mixtures* because the different components are easily seen. Other examples of suspensions include muddy water and Italian salad dressing.

The particles in a suspension are fairly large, and they scatter or block light. This often makes a suspension difficult to see through. But the particles are too heavy to remain mixed without being stirred or shaken. If a suspension is allowed to sit undisturbed, the particles will settle out, as in a snow globe.

A suspension can be separated by passing it through a filter. The liquid or gas passes through, but the solid particles are large enough to be trapped by the filter, as shown in **Figure 16.**

Figure 16 *Dirty air is a suspension that could damage a car's engine. The air filter in a car separates dust from air to keep the dust from getting into the engine.*

APPLY

Shake Well Before Use

Many medicines, such as remedies for upset stomach, are suspensions. The directions on the label instruct you to shake the bottle well before use. Why must you shake the bottle? What problem could arise if you don't?

Colloids

Figure 17 *This dessert includes two delicious examples of colloids—fruity gelatin and whipped cream.*

Some mixtures have properties of both solutions and suspensions. These mixtures are known as colloids (KAWL OYDZ). A **colloid** is a mixture in which the particles are dispersed throughout but are not heavy enough to settle out. The particles in a colloid are relatively small and are fairly well mixed. Solids, liquids, and gases can be used to make colloids. You might be surprised at the number of colloids you encounter each day. Milk, mayonnaise, stick deodorant—even the gelatin and whipped cream in **Figure 17**—are colloids. The materials that compose these products do not separate between uses because their particles do not settle out.

Although the particles in a colloid are much smaller than the particles in a suspension, they are still large enough to scatter a beam of light shined through the colloid, as shown in **Figure 18.** Finally, unlike a suspension, a colloid cannot be separated by filtration. The particles are small enough to pass through a filter.

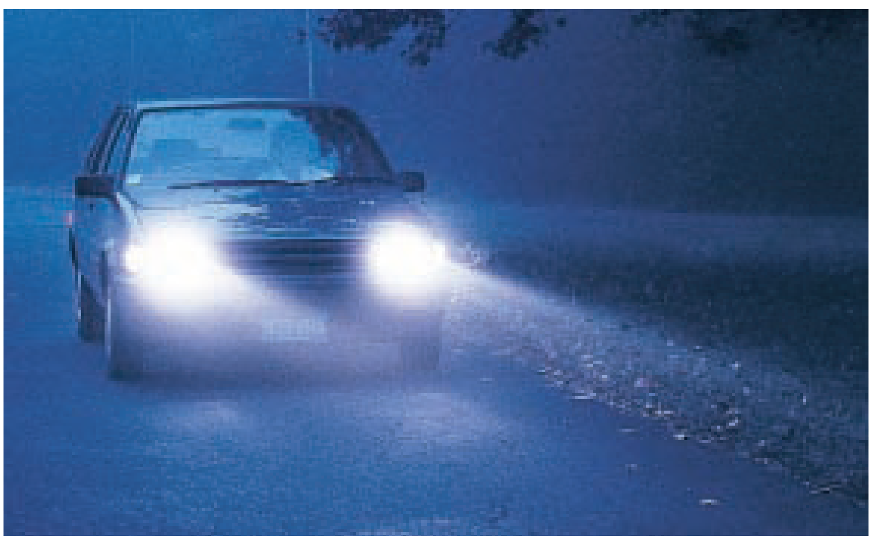


Figure 18 *The particles in the colloid fog scatter light, making it difficult for drivers to see the road ahead.*

LabBook

Make a colloid found in your kitchen on page 643 of the LabBook.

REVIEW

1. List two methods of making a solute dissolve faster.
2. Identify the solute and solvent in a solution made from 15 mL of oxygen and 5 mL of helium.
3. **Comparing Concepts** What are three differences between solutions and suspensions?

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TOPIC: Mixtures
GO TO: www.scilinks.org
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Chapter Highlights

SECTION 1

Vocabulary

element *(p. 82)*
pure substance *(p. 82)*
metals *(p. 85)*
nonmetals *(p. 85)*
metalloids *(p. 85)*

Section Notes

- A substance in which all the particles are alike is a pure substance.
- An element is a pure substance that cannot be broken down into anything simpler by physical or chemical means.
- Each element has a unique set of physical and chemical properties.
- Elements are classified as metals, nonmetals, or metalloids, based on their properties.

SECTION 2

Vocabulary

compound *(p. 86)*

Section Notes

- A compound is a pure substance composed of two or more elements chemically combined.
- Each compound has a unique set of physical and chemical properties that are different from the properties of the elements that compose it.
- The elements that form a compound always combine in a specific ratio according to their masses.
- Compounds can be broken down into simpler substances by chemical changes.

Labs

Flame Tests *(p. 640)*

Skills Check

Math Concepts

CONCENTRATION The concentration of a solution is a measure of the amount of solute dissolved in a solvent. For example, a solution is formed by dissolving 85 g of sodium nitrate in 170 mL of water. The concentration of the solution is calculated as follows:

$$\frac{85\text{ g sodium nitrate}}{170\text{ mL water}} = 0.5\text{ g/mL}$$

Visual Understanding

THREE CATEGORIES OF ELEMENTS Elements are classified as metals, nonmetals, or metalloids, based on their properties. The chart on page 85 provides a summary of the properties that distinguish each category.

SEPARATING MIXTURES Mixtures can be separated through physical changes based on differences in the physical properties of their components. Review the illustrations on page 91 for some techniques for separating mixtures.

SECTION 3

Vocabulary

mixture *(p. 90)*
solution *(p. 92)*
solute *(p. 92)*
solvent *(p. 92)*
concentration *(p. 94)*
solubility *(p. 94)*
suspension *(p. 96)*
colloid *(p. 97)*

Section Notes

- A mixture is a combination of two or more substances, each of which keeps its own characteristics.
- Mixtures can be separated by physical means, such as filtration and evaporation.
- The components of a mixture can be mixed in any proportion.
- A solution is a mixture that appears to be a single substance but is composed of a solute dissolved in a solvent. Solutions do not settle, cannot be filtered, and do not scatter light.
- Concentration is a measure of the amount of solute dissolved in a solvent.

- The solubility of a solute is the amount of solute needed to make a saturated solution using a given amount of solvent at a certain temperature.
- Suspensions are heterogeneous mixtures that contain particles large enough to settle out, be filtered, and block or scatter light.
- Colloids are mixtures that contain particles too small to settle out or be filtered but large enough to scatter light.

Labs

A Sugar Cube Race! *(p. 642)*
Making Butter *(p. 643)*
Unpolluting Water *(p. 644)*

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KEYWORD: HSTMIX

SCILINKS NSTA

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TOPIC: The *Titanic*	***sci*LINKS NUMBER:** HSTP080
TOPIC: Elements	***sci*LINKS NUMBER:** HSTP085
TOPIC: Compounds	***sci*LINKS NUMBER:** HSTP090
TOPIC: Mixtures	***sci*LINKS NUMBER:** HSTP095

Chapter Review

USING VOCABULARY

Complete the following sentences by choosing the appropriate term from the vocabulary list to fill in each blank:

1. A __?__ has a definite ratio of components.
2. The amount of solute needed to form a saturated solution is the __?__ of the solute.
3. A __?__ can be separated by filtration.
4. A pure substance must be either a(n) __?__ or a(n) __?__.
5. Elements that are brittle and dull are __?__.
6. The substance that dissolves to form a solution is the __?__.

UNDERSTANDING CONCEPTS

Multiple Choice

7. Which of the following increases the solubility of a gas in a liquid?
   a. increasing the temperature
   b. stirring
   c. decreasing the temperature
   d. decreasing the amount of liquid

8. Which of the following best describes chicken noodle soup?
   a. element
   b. mixture
   c. compound
   d. solution

9. Which of the following does not describe elements?
   a. all the particles are alike
   b. can be broken down into simpler substances
   c. have unique sets of properties
   d. can join together to form compounds

10. A solution that contains a large amount of solute is best described as
    a. unsaturated.
    b. concentrated.
    c. dilute.
    d. weak.

11. Which of the following substances can be separated into simpler substances only by chemical means?
    a. sodium
    b. salt water
    c. water
    d. gold

12. Which of the following would not increase the rate at which a solid dissolves?
    a. decreasing the temperature
    b. crushing the solid
    c. stirring
    d. increasing the temperature

13. An element that conducts thermal energy well and is easily shaped is a
    a. metal.
    b. metalloid.
    c. nonmetal.
    d. None of the above

14. In which classification of matter are the components chemically combined?
    a. alloy
    b. colloid
    c. compound
    d. suspension

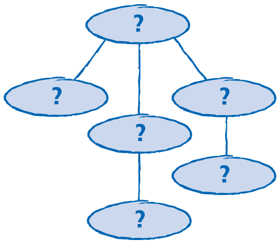
Short Answer

15. What is the difference between an element and a compound?

16. When nail polish is dissolved in acetone, which substance is the solute and which is the solvent?

Concept Mapping

17. Use the following terms to create a concept map: matter, element, compound, mixture, solution, suspension, colloid.



CRITICAL THINKING AND PROBLEM SOLVING

18. Describe a procedure to separate a mixture of salt, finely ground pepper, and pebbles.

19. A light green powder is heated in a test tube. A gas is given off, while the solid becomes black. In which classification of matter does the green powder belong? Explain your reasoning.

20. Why is it desirable to know the exact concentration of solutions rather than whether they are concentrated or dilute?

21. Explain the three properties of mixtures using a fruit salad as an example.

22. To keep the "fizz" in carbonated beverages after they have been opened, should you store them in a refrigerator or in a cabinet? Explain.

MATH IN SCIENCE

23. What is the concentration of a solution prepared by mixing 50 g of salt with 200 mL of water?

24. How many grams of sugar must be dissolved in 150 mL of water to make a solution with a concentration of 0.6 g/mL?

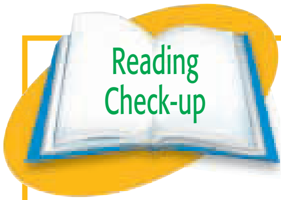
INTERPRETING GRAPHICS

25. Use Figure 14 on page 67 to answer the following questions:
    a. Can 50 g of sodium chloride dissolve in 100 mL of water at 60°C?
    b. How much cerium sulfate is needed to make a saturated solution in 100 mL of water at 30°C?
    c. Is sodium chloride or sodium nitrate more soluble in water at 20°C?

26. Dr. Sol Vent tested the solubility of a compound. The data below was collected using 100 mL of water. Graph Dr. Vent's results. To increase the solubility, would you increase or decrease the temperature? Explain.

Temperature (°C)	10	25	40	60	95
Dissolved solute (g)	150	70	34	25	15

27. What type of mixture is shown in the photo below? Explain.



Take a minute to review your answers to the Pre-Reading Questions found at the bottom of page 80. Have your answers changed? If necessary, revise your answers based on what you have learned since you began this chapter.

Science, Technology, and Society

Perfume: Fragrant Solutions

Making perfume is an ancient art. It was practiced, for example, by the ancient Egyptians, who rubbed their bodies with a substance made by soaking fragrant woods and resins in water and oil. From certain references and formulas in the Bible, we know that the ancient Israelites also practiced the art of perfume making. Other sources indicate that this art was also known to the early Chinese, Arabs, Greeks, and Romans.

▲ *Perfumes have been found in the tombs of Egyptians who lived more than 3,000 years ago.*

Only the E-scent-ials

Over time, perfume making has developed into a complicated art. A fine perfume may contain more than 100 different ingredients. The most familiar ingredients come from fragrant plants or flowers, such as sandalwood or roses. These plants get their pleasant odor from their essential oils, which are stored in tiny, baglike parts called sacs. The parts of plants that are used for perfumes include the flowers, roots, and leaves. Other perfume ingredients come from animals and from man-made chemicals.

Making Scents

Perfume makers first remove essential oils from the plants using distillation or reactions with solvents. Then the essential oils are blended with other ingredients to create perfumes. Fixatives, which usually come from animals, make the other odors in the perfume last longer. Oddly enough, most natural fixatives smell awful! For example, civet musk is a foul-smelling liquid that the civet cat sprays on its enemies.

Taking Notes

When you take a whiff from a bottle of perfume, the first odor you detect is called the top note. It is a very fragrant odor that evaporates rather quickly. The middle note, or modifier, adds a different character to the odor of the top note. The base note, or end note, is the odor that lasts the longest.

▲ *Not all perfume ingredients smell good. The foul-smelling oil from the African civet cat is used as a fixative in some perfumes.*

Smell for Yourself

▶ Test a number of different perfumes and colognes to see if you can identify three different notes in each.

Science Fiction

"The Strange Case of Dr. Jekyll and Mr. Hyde"

by Robert Louis Stevenson

A vicious, detestable man murders an old gentleman. A wealthy and respectable scientist commits suicide. Are these two tragedies connected in some way?

Dr. Henry Jekyll is an admirable member of society. He is a doctor and a scientist. Although wild as a young man, Jekyll has become cold and analytical as he has aged and has pursued his scientific theories. Now he wants to understand the nature of human identity. He wants to explore the different parts of the human personality that usually fit together smoothly to make a complete person. His theory is that if he can separate his personality into "good" and "evil" parts, he can get rid of his evil side and lead a happy, useful life. So Jekyll develops a chemical mixture that will allow him to test his theory. The results are startling!

Who is the mysterious Mr. Hyde? He is not a scientist. He is a man of action and anger, who sparks fear in the hearts of those he comes in contact with. Where did he come from? What does he do? How can local residents be protected from his wrath?

Robert Louis Stevenson's story of the decent doctor Henry Jekyll and the violent Edward Hyde is a classic science-fiction story. When Jekyll mixes his "salts" and drinks his chemical mixture, he changes his life—and Edward Hyde's—completely. To find out more, read Stevenson's "The Strange Case of Dr. Jekyll and Mr. Hyde" in the *Holt Anthology of Science Fiction.*

TIMELINE

UNIT

2

Motion and Forces

It's hard to imagine a world where nothing ever moves. Without motion or forces to cause motion, life would be very dull! The relationship between force and motion is the subject of this unit. You will learn how to describe the motion of objects, how forces affect motion, and how fluids exert force. This timeline shows some events and discoveries that have occurred as scientists have worked to understand the motion of objects here on Earth and in space.

Around 250 B.C.

Archimedes, a Greek mathematician, develops the principle that bears his name. The principle relates the buoyant force on an object in a fluid to the amount of fluid the object displaces.

Around 240 B.C.

Chinese astronomers are the first to record a sighting of Halley's Comet.

1905

While employed as a patent clerk, German physicist Albert Einstein publishes his special theory of relativity. The theory states that the speed of light is constant, no matter what the reference point is.

1921

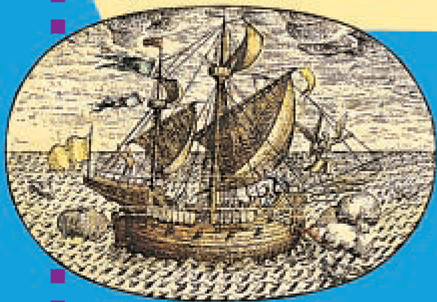
Bessie Coleman becomes the first African-American woman licensed to fly an airplane.

1947

While flying a Bell X-1 rocket-powered airplane, American pilot Chuck Yeager becomes the first human to travel faster than the speed of sound.

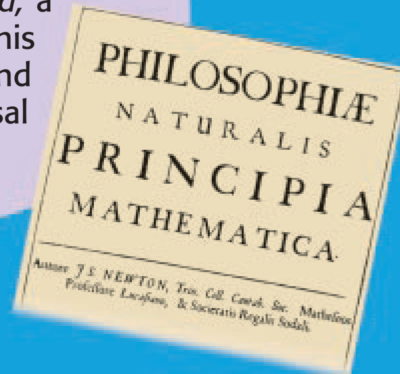
1519

Portuguese explorer Ferdinand Magellan begins the first voyage around the world.



1687

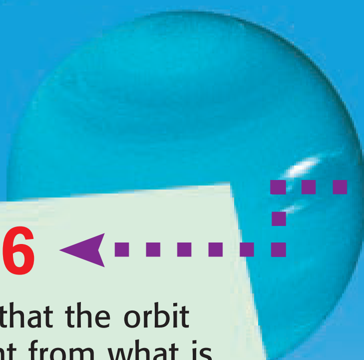
Sir Isaac Newton, a British mathematician and scientist, publishes *Principia,* a book describing his laws of motion and the law of universal gravitation.



1764

In London, Wolfgang Amadeus Mozart composes his first symphony—at the age of 9.

1846



After determining that the orbit of Uranus is different from what is predicted from the law of universal gravitation, scientists discover Neptune, shown here, whose gravitational force is causing Uranus's unusual orbit.

1971

American astronaut Alan Shepard takes a break from gathering lunar data to play golf on the moon during the *Apollo 14* mission.

1990

The *Magellan* spacecraft begins orbiting Venus for a four-year mission to map the planet. The spacecraft uses the sun's gravitational force to propel it to Venus without burning much fuel.

1999

NASA launches the Mars *Polar Lander* spacecraft, one of a series sent to explore Mars.