2.1 Properties of Matter

CHEMISTRY & YOU

Q: Why are windows made of glass? You look through windows every day at home or at school. Most windows are made of glass. Glass is transparent, meaning you can see through it. Glass is smooth and hard. It is also easy to shatter. Transparency, smoothness, and hardness are properties of glass. 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?***

BUILD Vocabulary

mass the amount of matter in an object

volume the amount of space an object takes up

extensive property a property that depends on the amount of matter

intensive property a property that depends on the type of matter, not the amount

RELATED WORD FORMS

The word *extent* means "a range." You can think of extensive properties as having a range of values that depend on the amount of matter.

Describing Matter

What properties do you observe when you examine matter? Is a solid hard or soft? Is a liquid clear or cloudy? Does a gas have an odor or not? The properties used to describe matter can be classified as either extensive or intensive properties.

Extensive Properties Matter is anything that has mass and takes up space. **Mass** is a measure of the amount of matter in an object. The watering can in the picture below has more matter than the soda can does. So the mass of the watering can is greater than the mass of the soda can. The **volume** of an object is a measure of the space the object takes up. The watering can takes up more space than the soda can does. So the watering can has a greater volume. 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 The watering can and the soda can are made of different materials. The soda can is mostly aluminum. The watering can is mostly copper. Each of these materials has different properties. Aluminum is silver in color. Copper is reddish-yellow. Color is an example of an intensive property. An **intensive property** is a property that depends on the type of matter in a sample. An intensive property does not depend on the amount of matter in the sample.

Extensive and Intensive Properties The soda can and watering can have extensive properties that include mass and volume. Their intensive properties include color, hardness, and shininess.

Identifying a Substance The soda can and the watering can have different chemical makeups, or compositions. Matter that has a uniform and definite composition is called a **substance.** Aluminum and copper are examples of substances. Substances are sometimes called pure substances. Every sample of a substance has the same intensive properties. For example, a copper watering can has the same intensive properties as a piece of copper wire.

Aluminum and copper share some properties. They are both malleable, which means they can be hammered into sheets without breaking. They are also both shiny. Aluminum and copper have some different properties. They are different in color. Pure copper is harder than pure aluminum. Copper is a better conductor of heat and electricity than aluminum. Malleability, shininess, color, hardness, and conductivity are 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.

The table below lists some physical properties for a few substances. The table shows the state of each substance at room temperature, the color of each substance, and the melting and boiling points. Physical properties can help you to identify substances. Notice that water is a colorless liquid at room temperature that boils at 100°C and melts at 0°C. Could a liquid that boils at 78°C and melts at −117°C be water? No, it has different properties from water. According to the table, this substance is ethanol.

Key Question Why do all samples of a substance have the same intensive properties? **Every sample of a given substance has identical intensive properties because every sample has the same composition.**

Identifying Substances This table shows properties that can be used to help identify substances.

Go to your Chemistry Skills and Math Workbook to practice interpreting tables.

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

BUILD Vocabulary

substance matter that has a uniform and definite composition

physical property a property that can be observed or measured without changing the identity of the substance

WORD ORIGINS

The word *substance* comes from a Latin word that means "material." A substance is made of material.

BUILD Vocabulary

solid matter that has a definite shape and volume

liquid matter that has a definite volume but not a definite shape

gas matter that does not have a definite shape or volume

vapor the gaseous state of a substance that is a liquid or solid at room temperature

physical change a change in the properties of a substance that does not change the composition of the substance

MULTIPLE MEANINGS

In chemistry, the word *state* refers to the form of matter. In everyday life, you probably think of a state as one of the areas that make up the United States.

States of Matter

What words can you use to describe water? You might use ice, water, and steam. These words describe three different physical states of water. Ice is solid water. Water that flows and feels wet is a liquid. Steam is vaporized water. It is produced when water boils. Like water, most substances can be in three states. These three states of matter have certain characteristics. The figure to the right shows a model of each state of matter.

Solids A **solid** is a form of matter that has a definite shape and volume. Its shape does not depend on the shape of its container. The particles in a solid are packed together tightly, often in an orderly way. As a result, solids are almost incompressible. They cannot be easily squeezed into a smaller volume. Solids also expand only slightly when heated.

Liquids The particles in a liquid are in close contact with one another. However, they are not held together in a rigid or orderly way. Particles in a liquid flow from one place to another. This is why a liquid takes the shape of its container. The volume of the liquid does not change as its shape changes. A **liquid** is a form of matter that has a definite volume but not a definite shape. Liquids are almost incompressible. Most liquids expand slightly when heated.

Gases Like a liquid, a gas takes the shape of its container. However, a gas can expand to fill any volume. A **gas** is a form of matter that does not have a definite shape or volume. The particles in a gas are often much farther apart than the particles in a liquid. Because of the space between particles, gases are easily compressed into a smaller volume. The table below compares the three states of matter.

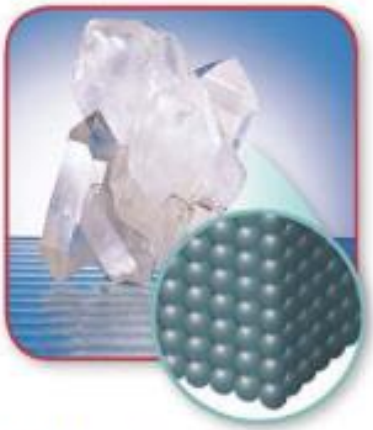
The word vapor is sometimes used to mean gas. But these two words have different meanings. The term *gas* is used for substances like oxygen that exist in the gaseous state at room temperature. (Gaseous is the adjective form of gas.) **Vapor** describes the gaseous state of a substance that is usually a solid or a liquid at room temperature, like water vapor.

Key Question What are three states of matter? **Three states of matter are solid, liquid, and gas.**

Properties of Solids, Liquids, and Gases

	Solids	Liquids	Gases
Fixed shape	Yes	No	No
Fixed volume	Yes	Yes	No
Space between particles	Touching	Small	Large
Particle movement	Fixed	Flowing	Free
Compressible	No	No	Yes
Expands when heated	Slightly	Slightly	Yes

of matter
online.



Solid Particles are packed closely together so that they form a definite shape.

Liquid Particles are close together, but they can flow freely past one another.

Gas Particles are far apart and can move freely.

Physical Changes

The state of ice changes when ice melts, but ice and water are the same substance. Melting is a physical change. A **physical change** alters some properties of a material, but it does not change the composition of the material.

Physical changes can be classified as reversible or irreversible. Words such as freeze, melt, and condense are used to describe reversible physical changes. If you cool liquid water below its melting point, it will turn into ice. If you warm the ice above its melting point, it will change back into a liquid. Changes of state are physical changes that are reversible. Words such as tear, break, cut, and crush describe irreversible physical changes. When you break an egg or a window, you can't put it back together.

BUILD Connections

you've probably seen your breath fog up a windshield. this can happen easily if it's cold outside. Water vapor in your breath condenses and changes to water droplets. If the air inside the car is warm, the droplets quickly change back to water vapor.

Key Question How can physical changes be classified? **They can be classified as reversible or irreversible.**

2.1 LessonCheck

Key Concept Check

1. **Review** 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.

Think Critically

4. **Compare and Contrast** In what way are liquids and gases alike? In what way are liquids and solids different from one another?

CHEMISTRY & YOU

5. Glass is used to make windows. Copper is used to make electrical wires. What properties of glass make it useful for windows? Why wouldn't you use copper to make windows? (Hint: See page 29.)

BIG IDEA

CHEMISTRY AS THE CENTRAL SCIENCE

6. How is understanding the properties of matter helpful in fields other than 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 how are grounds kept out of a coffee cup? In this lesson, you will learn how to classify and separate mixtures.

Key Questions

- *How can mixtures be classified?*
- *How can mixtures be separated ?*

BUILD Vocabulary

mixture a physical blend of two or more parts

heterogeneous mixture a mixture that has a composition that is not uniform

homogeneous mixture a mixture that has a uniform composition

solution a homogeneous mixture

phase the part of a sample with a uniform composition

PREFIXES

The prefix *hetero-* means "different." One part of a heterogeneous mixture is different from another part of the mixture. The prefix *homo-* means "the same." Every part of a homogeneous mixture is the same as every other part of the mixture.

Classifying Mixtures

You can find lettuce, tomatoes, cheese, green peppers, and many other items at a salad bar like the one below. You can choose which foods you want in your salad and how much of each food to add. When complete, your salad mixture will probably have several different types and amounts of food. A **mixture** is a physical blend of two or more components, or parts.

Most types of matter that you see are mixtures. Some mixtures are easier to recognize than others. It is easy to see that chicken noodle soup is a mixture of chicken, noodles, and broth. It is harder to see that air is a mixture of gases. Chicken noodle soup and air represent two different types of mixtures—heterogeneous mixtures and homogeneous mixtures.

Heterogeneous Mixtures The ingredients in the chicken noodle soup are not evenly distributed throughout the mixture. There are usually different amounts of chicken and noodles in each spoonful. A mixture that does not have a uniform composition throughout is a **heterogeneous mixture.**

Salads Are Mixtures You can choose the amount of each item you want from a salad bar. Your salad is unlikely to have the same composition as other salads containing the same items.

Two Types of Mixtures
Olive oil and vinegar are homogeneous mixtures. Mixing olive oil and vinegar forms a heterogeneous mixture with two distinct phases.

Homogeneous Mixtures The olive oil in the figure above does not look like a mixture, but it is. It is made of substances that are evenly spread throughout the mixture. The same is true for the vinegar. Olive oil and vinegar are homogeneous mixtures. A **homogeneous mixture** is a mixture that has a uniform composition throughout. Another name for a homogeneous mixture is a **solution.** Many solutions are liquids. Some are gases, like air. Others are solids, like steel.

The term **phase** is used to describe any part of a sample with uniform composition and properties. A homogeneous mixture has a single phase. A heterogeneous mixture has at least two phases. Each layer in the heterogeneous oil and vinegar mixture is a phase.

Key Question How can mixtures be classified? **Mixtures can be classified as heterogeneous mixtures or as homogeneous mixtures based on the distribution of their components.**

BUILD Vocabulary

filtration a process that separates a solid from a liquid in a heterogeneous mixture

distillation a process that separates a liquid from a mixture by boiling

WORD ORIGINS

The word *distill* comes from the Latin word *distillare*, meaning "to trickle down in small drops."

Separating Mixtures

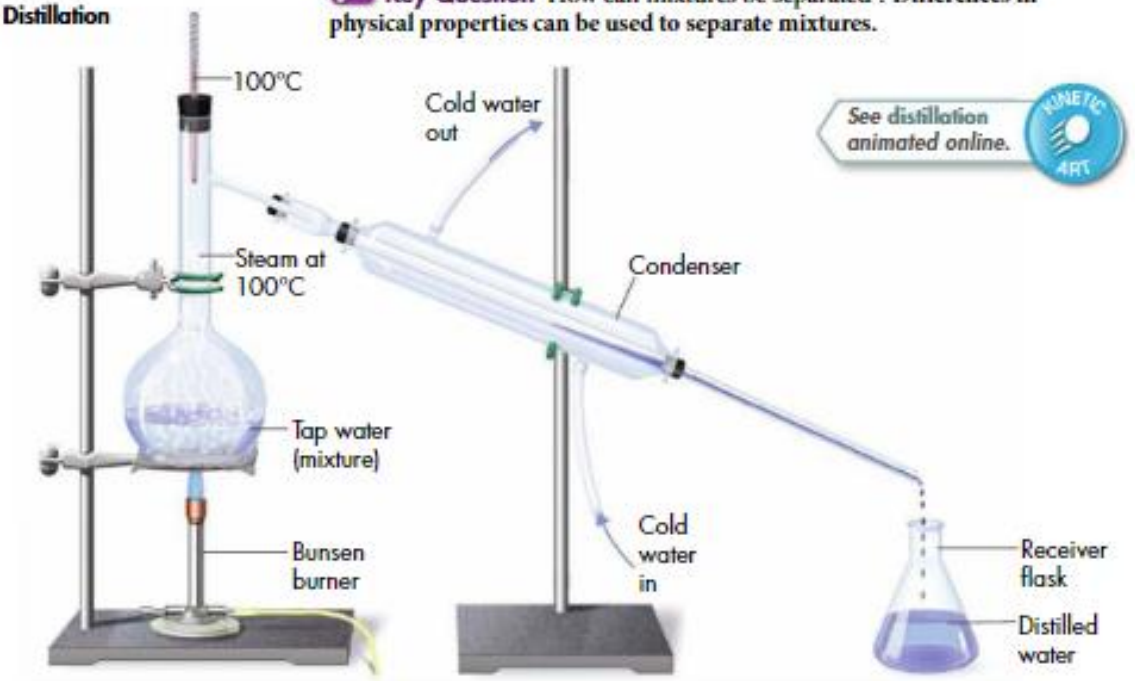
You can use a fork to remove the parts you do not like in a salad. Many mixtures are not as easy to separate. Consider a mixture of oil and vinegar. You might have noticed that oil floats on vinegar. To separate this mixture, you can carefully pour off the oil layer. You can also separate the parts by cooling the mixture. Since oil and vinegar freeze at different temperatures, you can remove the frozen part from the liquid part.

Filtration A coffee filter separates ground coffee beans from brewed coffee. The liquid coffee passes through the paper filter. The solid coffee grounds stay in the filter because they are too big to pass through. The filter paper used to separate mixtures in laboratories is like a coffee filter. A mixture is poured into a funnel lined with filter paper. Solid particles that are too big to go through the filter stay in the funnel. The liquid passes through the filter paper. The process that separates a solid from a liquid in a heterogeneous mixture is called **filtration.**

Distillation Tap water is a homogeneous mixture of water and dissolved substances. Distillation is one way to separate the water from these other substances. During a **distillation,** a liquid is boiled to produce a vapor that is then condensed back into a liquid. The figure below shows a distillation. Tap water is heated to make water vapor. Pure water is collected at the end. The substances dissolved in tap water have much higher boiling points than the water itself. These substances are left behind in the distillation flask.

Distillation

Key Question How can mixtures be separated? **Differences in physical properties can be used to separate mixtures.**



❶ The flask is heated. Liquid water changes into water vapor. The other substances in the tap water stay in the flask.

❷ Steam rises out of the flask and flows into a glass tube in the condenser. Cold water is piped into the condenser around this tube to cool the steam.

❸ The steam condenses on the inside of the glass tube. This liquid water drips into the receiver flask. The water is now distilled.

Sample Problem 2.1

Separating a Heterogeneous Mixture

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

❶ **Analyze** **Identify the relevant concepts.** You need to know properties of both aluminum and iron to find a way to separate the nails.

❷ **Solve** **Apply concepts to this situation.**

List the properties of each substance in the mixture.

Aluminum	Iron
• metal	• metal
• gray color	• gray color
• doesn't dissolve in water	• doesn't dissolve in water
• not attracted to magnet	• attracted to magnet

Identify a property that can be used to separate the different substances from one another.

Iron is attracted to a magnet. Aluminum is not attracted to a magnet. You could use a magnet to remove the iron nails from a mixture of iron and aluminum.

Practice Problem

7. 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

Key Concept Check

8. **Identify** How are mixtures classified?

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

Vocabulary Check *Choose a highlighted word from the lesson to complete the sentence correctly.*

10. A mixture with an uneven distribution of parts is a(n) _____ .

Think Critically

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

CHEMISTRY & YOU

12. What process is used to separate ground coffee beans from brewed coffee? (Hint: See page 34.)

BIG IDEA CHEMISTRY AS THE CENTRAL SCIENCE

13. Give three examples of mixtures you have separated at home and explain how you separated them.

2.3 Elements and Compounds

CHEMISTRY & YOU

Q: Why does burned toast taste so bad? Bread that is toasted to a nice golden brown color can be a tasty part of breakfast. But most people would agree that bread that is burned and black tastes bad. There is a fine line between toasting or grilling food and burning it. Adding intense heat causes some compounds in foods to break down to their simpler chemical building blocks.

Key Questions

- *How are elements and compounds different?*
- *How can substances and mixtures be distinguished?*
- *What do chemists use to represent elements and compounds?*
- *Why is a periodic table useful?*

BUILD Vocabulary

element the simplest form of matter that has a unique set of properties

compound a substance that contains two or more elements that are chemically combined

chemical change a change that results in a substance with a different composition

Distinguishing Elements and Compounds

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 more than 100 known elements. Elements cannot be broken down into simpler substances. Compounds, however, can be broken down into simpler substances.

Compounds A **compound** is a substance that contains two or more elements that are chemically combined. The elements in a compound are combined in a fixed proportion. One example of a compound is sucrose, or table sugar. Carbon, oxygen, and hydrogen are chemically combined in table sugar. Every sample of table sugar contains twice as much hydrogen as oxygen. This means that the proportion of hydrogen to oxygen is fixed.

Chemical Change Physical methods cannot break compounds into simpler substances. For example, the act of boiling water cannot break the water into oxygen and hydrogen. Physical methods cannot cause a chemical change. A **chemical change** is a change that produces matter with a different composition than that of the original matter.

Chemical Change

MULTIPLE MEANINGS

You might have heard your English teacher use the word *compound* to describe words. For example, *basketball* is a compound word made up of the words *basket* and *ball*. Similarly, chemical compounds are made up of at least two or more elements.

❶ Adding too much heat to table sugar causes a chemical change.

❷ The table sugar reacts with oxygen in air to form carbon dioxide, water, and solid carbon.

When a compound breaks into simpler substances, a chemical change takes place. Heating can break down some compounds into simpler substances. The pictures on the previous page show how you can heat a layer of sugar in a pan until the sugar breaks down into solid carbon, carbon dioxide, and water vapor. Can these new substances also be broken down?

Carbon cannot break down any further because it is an element. Heat will not cause water to break down, but electricity will. When electricity passes through water, oxygen and hydrogen are produced.

Properties of Compounds The properties of a compound are often very different from those of the elements that make it up. For example, sugar is a sweet-tasting white solid made of carbon, hydrogen, and oxygen. Carbon is a black solid that has no taste. Hydrogen is a gas that burns in the presence of oxygen. Oxygen is a colorless gas that you breathe. The figure below shows some properties of the elements sodium and chlorine. You would not want to handle either element. Sodium is a soft, gray metal that reacts violently with water. Chlorine is a pale, yellow-green, poisonous gas. However, when combined, these elements make table salt, a white solid you can eat.

Key Question How are elements and compounds different? **Compounds can be broken down into simpler substances by chemical means, but elements cannot.**

BUILD Understanding

T-Chart Make a T-chart for elements and compounds. In the left column, write Elements. In the right column, write Compounds. Use this chart to compare these two classes of substances.

Comparing Properties of Elements and Compounds

Sodium
The vapor of this element produces the light in some street lamps.

Chlorine
This element can be used to kill harmful organisms in swimming pools.

Sodium chloride
This compound is used to season and preserve food.

Distinguishing Substances and Mixtures

Can you tell if a sample of matter is a substance or a mixture based only on how it looks? That could be difficult. After all, homogeneous mixtures and substances both appear to be made of only one kind of matter. Sometimes you can decide by thinking about whether there is more than one kind of the material in question. For example, you can buy whole milk, low fat milk, skim milk, light cream, or heavy cream. You could conclude that milk and cream are mixtures because there are many different kinds. You might infer that these mixtures are different because they contain different amounts of fat.

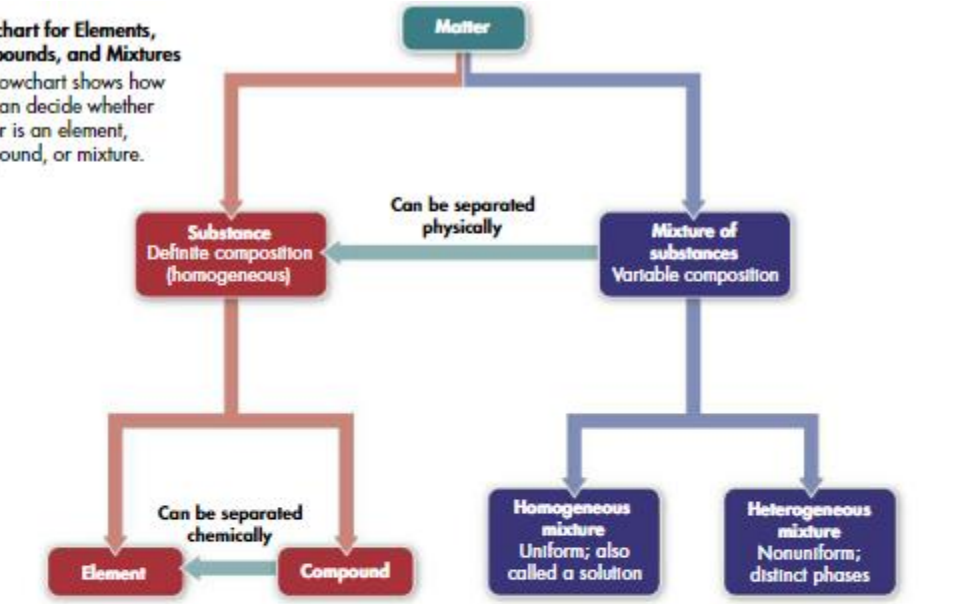
You can use the general characteristics of substances and mixtures to tell them apart. The flowchart below shows how to tell if matter is an element, compound, or mixture.

Key Question How can substances and mixtures be distinguished ?

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.

Flowchart for Elements, Compounds, and Mixtures
The flowchart shows how you can decide whether matter is an element, compound, or mixture.

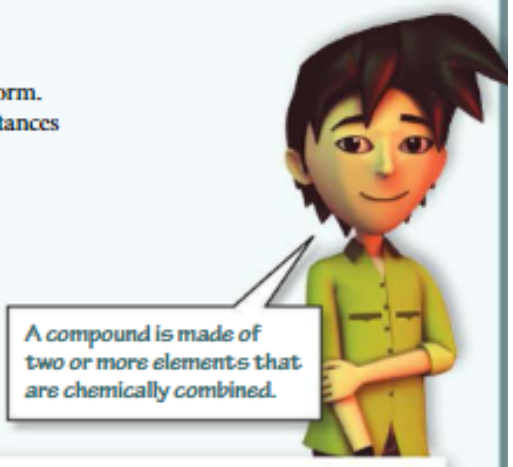


Mercury | Mercury sulfide | Stainless steel | Granite

Sample Problem 2.2

Classifying Materials

When a 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?



❶ 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.

❷ Solve **Apply concepts to this situation.**

List the known facts and important concepts.

- A blue-green solid is heated.
- A colorless gas and a black solid appear.

Determine if the substances are elements or compounds.

Blue-green solid: Two substances were produced by heating one substance. It is likely the blue-green solid was broken down. It is a compound.

Colorless gas and black solid: They could be elements or compounds. More tests are needed.

Practice Problems

14. Liquid A and Liquid B are clear liquids. They are placed in open containers and are allowed to evaporate. When evaporation is complete, there is a white solid in Container B. There is no solid in Container A. What can you infer about the two liquids?

Hint: Evaporation is a way of physically separating matter.

15. 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

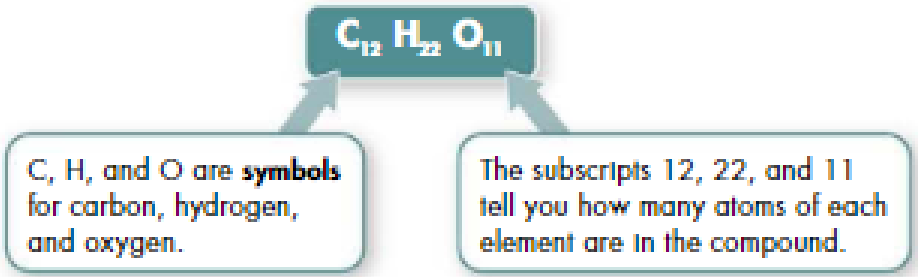
The names water and table salt do not tell you anything about the chemical composition of these substances. Words are not the best way to show what happens to matter during a chemical change. Chemists use chemical symbols to show the elements that make up matter.

People have used symbols to represent different kinds of matter for thousands of years. Today, each element has a **chemical symbol** that is made of one or two letters. The first letter of a chemical symbol is always capitalized. If there is a second letter, it is lowercase. Jöns Jacob Berzelius (1779–1848) thought of using letters from the Latin names of elements as symbols. The table below shows some symbols that do not match the English names of the elements.

Symbols and Latin Names for Some Elements

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

Chemical symbols are a quick way to write the chemical formulas of compounds. The symbols for carbon and hydrogen are C and H. The symbol for oxygen is O. The formula shown below is for sucrose, or table sugar. The subscripts tell you how many atoms of each type of element are in each unit of the compound. The formula for a given compound is always the same.



Key Question What do chemists use to represent elements and compounds? **Chemists use chemical symbols to represent elements and chemical formulas to represent compounds.**

The Periodic Table—A Preview

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 placed into groups based on their properties. You can use the periodic table to compare the properties of elements.

The figure below shows the modern periodic table. The symbol for each element is placed in a square. The atomic number for each element is placed at the top of each square. You can find that number above the symbol. The elements are listed in order of their atomic number. You can see that these numbers increase from left to right across a row. They also increase from the top to the bottom of a column. You will learn more about atomic numbers in Chapter 4. Hydrogen (H) has an atomic number of 1. This element is at the top left corner of the table. Helium (He) has an atomic number of 2. It is at the top right. You can use the atomic number or symbol to find any element in the table.

Elements are organized into periods and groups in the periodic table. Each row is a period. Each column is a group. Periods are numbered 1–7. Groups are numbered 1A–8A or 1B–8B.

BUILD Vocabulary

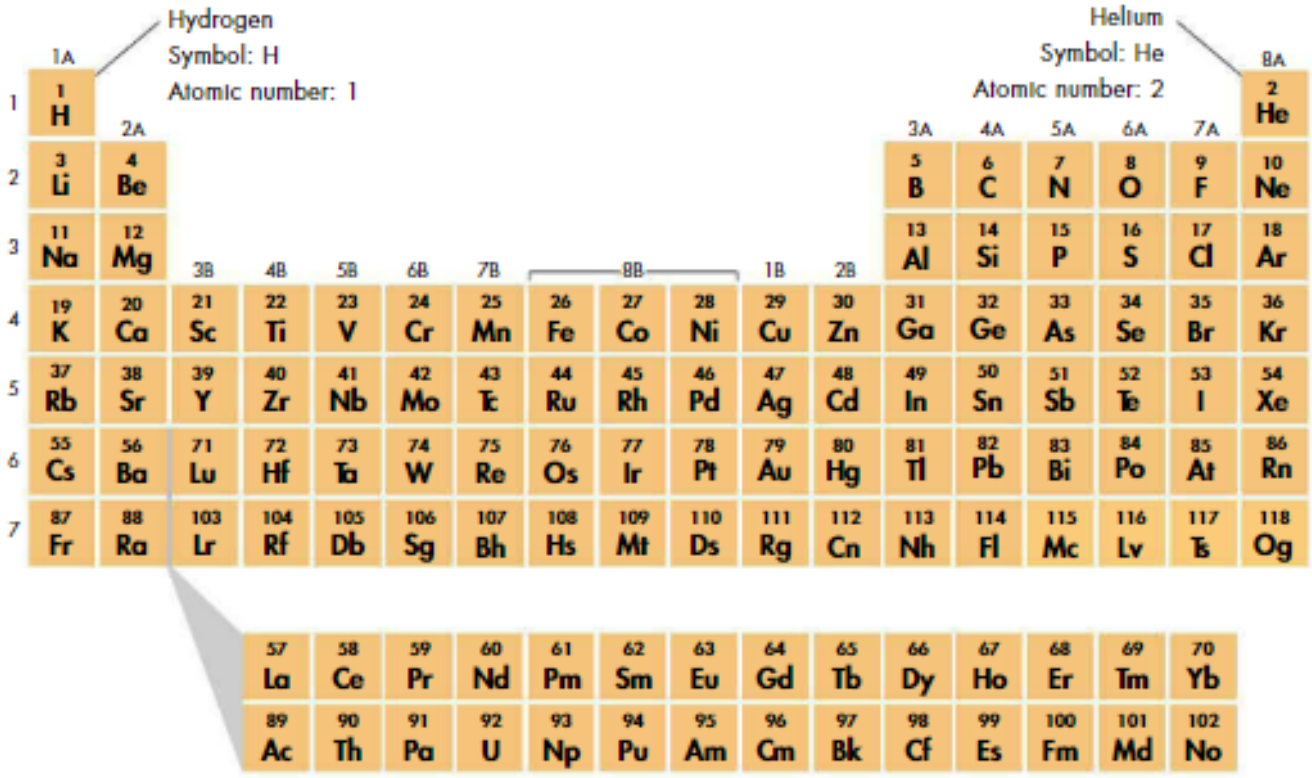
chemical symbol one or two letters used to represent an element

periodic table an organized grouping of the elements

USING PRIOR KNOWLEDGE

You have probably heard the words *chemical* and *symbol* used separately. The word chemical is used to refer to substances. The word symbol is used to refer to something that represents something else. A chemical symbol is one or two letters that represent an element.

The Periodic Table Elements are arranged by atomic number in the periodic table.



BUILD Vocabulary

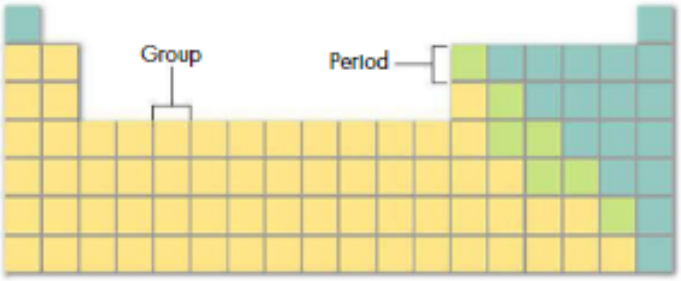
period a row in the periodic table

group a column in the periodic table

MULTIPLE MEANINGS

You probably think of a *period* as the amount of time you have to spend in class. It can mean "a block of time." In chemistry, period refers to rows in the periodic table. These rows have repeating, or periodic, properties.

Periods and Groups in the Periodic Table
Each row of the periodic table is called a period. Each column is called a group.



Periods Each row of the periodic table is called a **period.** The properties of the elements change as you move across each period.

Groups Each column of the periodic table is called a **group,** or family. Elements in the same group have similar chemical and physical properties. You will learn more about trends in the periodic table in Chapter 6.

Key Question Why is the periodic table useful ? **The periodic table allows you to compare the properties of one element (or group of elements) to another element (or group of elements).**

2.3 LessonCheck

Key Concept Check

16. **Compare** How is a compound different from an element?

17. **Compare** How can you distinguish a substance from a mixture?

18. **Identify** What are chemical symbols and chemical formulas used for?

19. **Explain** What makes the periodic table such a useful tool?

Vocabulary Check

Choose a highlighted word from the lesson to complete the sentence correctly.

20. A(n)_____ can be broken down into simpler substances.

21. Each column of the periodic table is called a(n) _____.

Think Critically

22. **Classify** Classify each of the following as an element, compound, or mixture.
a. table sugar **b.** tap water

23. **Identify** Write the chemical symbol for each of the following elements:
a. lead **b.** silver **c.** hydrogen

24. **Identify** Name two elements that have properties similar to those of the element calcium (Ca).

CHEMISTRY & YOU

25. What happens to the compounds in bread when it is overcooked? Why does this change the taste of the bread? (Hint: See page 37.)

2.4 Chemical Reactions

CHEMISTRY & YOU

Q: What happened to the match? Matches are often used to light candles on a birthday cake. A match is lit at the tip, and the fire burns down the match. A lit match is different from an unlit match. In this lesson, you will learn whether burning a match is a chemical change or a physical change.

Key Questions

- *What always happens during a chemical change?*
- *What are four possible clues that a chemical change has taken place?*
- *How are the mass of the reactants and the mass of the products of a chemical reaction related ?*

BUILD Vocabulary

chemical property the ability of a substance to undergo a chemical change

USING PRIOR KNOWLEDGE

Properties describe the characteristics of materials. Chemical properties describe the chemical characteristics of substances.

Chemical Changes

Iron forms a new substance when it rusts. That substance is iron oxide, or Fe_2O_3. You have heard words such as rust, burn, rot, bubble, and explode. These words often mean that a chemical change is happening. The ability of a substance to undergo a specific chemical change is called a chemical property. For example, when iron comes in contact with oxygen, a chemical reaction occurs that forms rust. The ability to form 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 chemical change happens.

Physical Versus Chemical Changes The figure below compares a physical change and a chemical change. Breaking charcoal into smaller pieces is a physical change. The smaller pieces of charcoal are made of the same substances as the larger pieces. The composition of matter never changes during a physical change. The composition of matter always changes during a chemical change. A chemical change happens when the charcoal is heated and burned. The substances in the charcoal react with oxygen in the air to form other substances.

react with oxygen in the air to form other substances.

Physical and Chemical Changes

Physical Change Breaking charcoal into smaller pieces is a physical change.

Chemical Change Burning charcoal is a chemical change.

Learn more about chemical changes online.

Chemical Reaction
Solid silver chloride forms when you mix solutions of silver nitrate and sodium chloride.

Chemical Reactions 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 that is present at the start of the reaction is called a **reactant.** Reactants change during the reaction. A substance that is produced during the reaction is called a **product.** The figure to the left shows a chemical reaction. A white solid forms when two clear liquids are mixed together. The liquids are solutions of silver nitrate and sodium chloride. These are the reactants. The solid is silver chloride. It is a product of the reaction.

Key Question What always happens during a chemical change? **The composition of matter always changes.**

Recognizing Chemical Changes

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

Energy Transfer Every chemical change involves a transfer of energy. Think of what happens when you cook food. Energy stored in fuel is used to cook the food. The fuel chemically combines with oxygen in the air when the burner is lit. This reaction gives off energy as heat and light, as shown in the figure below. The food absorbs some of the heat. The energy causes chemical changes to take place in the food.

Transfer of Energy
Energy transferred from burning fuel causes these eggs to undergo a chemical change.

Signs of a Chemical Change

Color Change
A test strip is dipped in a solution. The color change is used to determine if the solution is acidic.

Formation of a Precipitate
A reaction during cheese making causes milk to separate into solid curds and liquid whey.

Production of a Gas
Bubbles of carbon dioxide gas form when antacid tablets are dropped into a glass of water.

Color Change Food may change color and brown as it cooks. A color change is another sign that chemical changes are happening. The above left figure shows a color change. A substance on the paper changes from blue to red when it is placed in the solution. It reacts with the acid in the solution.

Formation of a Precipitate You can see other clues of a chemical change when you clean a bathtub. The ring of soap scum that forms in a bathtub is a precipitate. A **precipitate** is a solid that forms when two liquids react. The above center figure shows a precipitate that forms when cheese is made.

Production of a Gas You can also see another clue when you use a bathroom cleaner to remove soap scum. Many cleaners start to bubble when you spray them on the scum. The bubbles are produced because a gas is released by the chemical change that is happening. The above right figure of the antacid tablets also shows a reaction that forms a gas.

You need to be careful when you see clues of a chemical change. Just because you see one of the clues does not mean that a chemical change has taken place. The clue may be the result of a physical change. For example, energy is transferred when matter changes state. Bubbles form when you boil water or open a soda bottle. The only way to be sure that a chemical change has happened is to test the composition of a sample before and after the change.

Key Question What are four clues that a chemical change has taken place? **Clues to a chemical change include a transfer of energy, a change in color, the formation of a precipitate, or the production of a gas.**

BUILD Vocabulary

chemical reaction when one or more substances change into one or more new substances

reactant a substance present at the start of a reaction

product a substance produced during a reaction

precipitate a solid that forms when two liquids react

ROOT WORDS

The root word in *reactant* is *react*. To react means "to undergo a change." A reactant is the substance that changes during a chemical reaction.

BUILD Vocabulary

law of conservation of mass states that matter is conserved in any physical or chemical change

ROOT WORDS

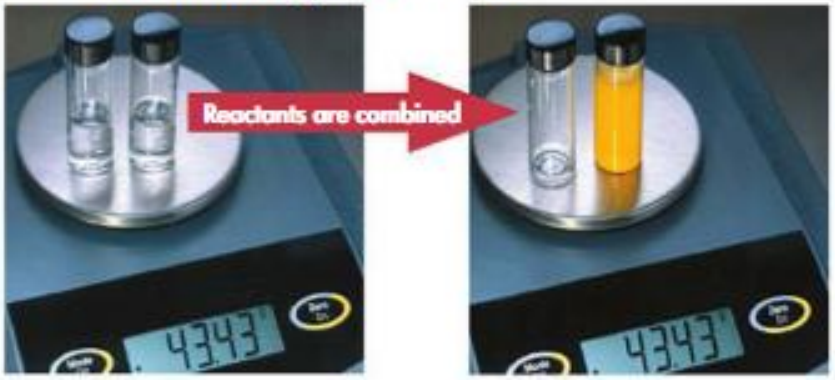
The root word in *conservation* is *conserve*. The verb conserve means "to stay constant." So conservation of mass means that the mass stays constant, or the same.

Conservation of Mass

When wood burns, substances in the wood combine with oxygen from the air. You can see the ash pile that forms during this reaction, and it seems smaller than the wood. The reaction seems to reduce the amount of matter. It actually does not. You cannot see the carbon dioxide and water vapor that are released into the air when wood burns. The mass of these gases plus the mass of the ashes is the same as the mass of the wood and oxygen. In other words, the total mass of the products is always the same as the total mass of the reactants. The **law of conservation of mass** states that mass is conserved in any physical change or chemical change. So mass is neither created nor destroyed. The photos below show how conservation of mass can be observed for chemical changes in a closed container.

Key Question How are the mass of the reactants and the mass of the products of a chemical reaction related? **During any chemical reaction, the mass of the products is always equal to the mass of the reactants.**

Conservation of Mass During a Chemical Reaction



❶ The mass of the reactants is measured.

❷ Mass does not change when products form.

2.4 LessonCheck

Key Concept Check

26. **Explain** How does a chemical change affect the composition of matter?

27. **List** Name four possible clues that a chemical change has taken place.

28. **Compare** In a chemical reaction, how does the mass of the reactants compare with the mass of the products?

Vocabulary Check

Choose a highlighted word from the lesson to complete the sentence correctly.

29. A(n) _____ forms during a chemical reaction.

Think Critically

30. **Classify** Classify the following changes as physical or chemical changes.
a. Water boils. **b.** A metal rusts.

31. **Explain** When is mass conserved according to the law of conservation of mass?

CHEMISTRY & YOU

32. Are the changes that happen to a burning match chemical or physical changes? How do you know? (Hint: See page 44.)

2 Study Guide

BIG IDEA

CHEMISTRY AS THE CENTRAL SCIENCE

Physical and chemical properties are used to describe matter. Physical properties include melting point and boiling point. Chemical properties include the ability to burn or rust. 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 (28)
- volume (28)
- extensive property (28)
- intensive property (28)
- substance (29)
- physical property (29)
- solid (30)
- liquid (30)
- gas (30)
- vapor (30)
- physical change (31)

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 (32)
- heterogeneous mixture (32)
- homogeneous mixture (33)
- solution (33)
- phase (33)
- filtration (34)
- distillation (34)

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 group of elements) to another element (or group of elements).

- element (36)
- compound (36)
- chemical change (36)
- chemical symbol (40)
- periodic table (41)
- period (42)
- group (42)

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 formation of a precipitate, or the production of a gas.
- During any chemical reaction, the mass of the products is always equal to the mass of the reactants.

- chemical property (43)
- chemical reaction (44)
- reactant (44)
- product (44)
- precipitate (45)
- law of conservation of mass (46)