Foundations of Chemistry

Classifying Matter

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	1. The atoms in all objects are the same.	
	2. You cannot always tell by an object's appearance whether it is made of more than one type of atom.	

Read to Learn

Understanding Matter

Have you ever seen a rock that has more than one color? Why are different parts of the rock different in color? Why might some parts of the rock feel harder than other parts? The parts of the rock look and feel different because they are made of different types of matter. **Matter** *is anything that has mass and takes up space.*

Look around. Many types of matter surround you. In your classroom, you might see things made of metal, wood, or plastic. In a park, you might see trees, soil, or water in a pond. Look up at the sky. You might see clouds and the Sun. All of these things are made of matter.

Everything you can see is matter. However, some things you cannot see also are matter. Air, for example, is matter because it has mass and takes up space. Sound and light are not matter. Forces and energy also are not matter. To decide whether something is matter, ask yourself if it has mass and takes up space.

An **atom** *is a small particle that is a building block of matter.* In this lesson, you will explore the parts of an atom. You will read how atoms can differ. You also will read how different arrangements of atoms make up the many types of matter.

Key Concepts

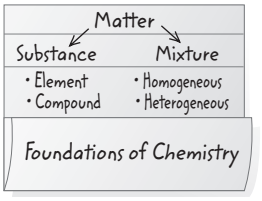
- What is a substance?
- How do atoms of different elements differ?
- How do mixtures differ from substances?
- How can you classify matter?

Study Coach

Building Vocabulary
Write each vocabulary term in this lesson on an index card. Shuffle the cards. After you have studied the lesson, take turns picking cards with a partner. Each of you should define the term using your own words.

FOLDABLES®

Make a layered Foldable to summarize the lesson.



Reading Check

1. Name What are the parts of an atom?

Visual Check

2. Identify Which part of an atom exists outside of the nucleus?

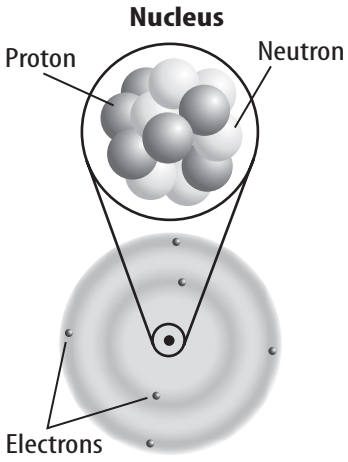
Key Concept Check

3. Define What is a substance?

Atoms

Look at the diagram of an atom in the figure below. At the center of an atom is the nucleus. Protons and neutrons make up the nucleus. Electrons move in an area outside of the nucleus.

Parts of an Atom



Protons have a positive charge. Neutrons have a neutral charge. Electrons have a negative charge. Electrons move quickly throughout an area around the nucleus called the electron cloud.

Not all atoms have the same number of protons, neutrons, and electrons. Atoms that have different numbers of protons differ in their properties. You will read more about the differences in atoms later in this lesson.

An atom is almost too small to imagine. Think about how thin a human hair is. The diameter of a human hair is about a million times greater than the diameter of an atom. Also, an atom is about 10,000 times wider than its nucleus! Even though atoms are tiny, they determine the properties of the matter they compose.

Substances

Atoms make up most of the matter on Earth. Atoms can combine and arrange in millions of different ways. In fact, these different combinations and arrangements of atoms determine the makeup of the various types of matter. Matter can be divided into two main classifications—substances and mixtures.

A **substance** *is matter with a composition that is always the same.* This means that a given substance is always made up of one or more atoms in the same combinations. Aluminum, oxygen, water, and sugar are examples of substances. A sample of any one of these substances, or any other substance, always has the same composition, or makeup. Any sample of aluminum is always made up of the same type of atoms. A sample of oxygen, sugar, or water always has the same combination of atoms as any other sample of that substance.

There are two types of substances. Substances can be elements or compounds.

Elements

Look at the periodic table of elements on the inside back cover of this book. Find the substances oxygen and aluminum. They are elements. *An* **element** *is a substance that consists of just one type of atom*. We currently know of about 115 elements. As a result, there are about 115 different types of atoms. Each type of atom contains a different number of protons in its nucleus. For example, each aluminum atom has 13 protons. The number of protons in an atom is the atomic number of the element. As the figure below shows, the atomic number of aluminum is 13.

The atoms of most elements exist as individual atoms. A roll of pure aluminum foil consists of trillions of individual aluminum atoms. However, the atoms of some elements usually exist in groups. For example, the oxygen atoms in air exist in pairs. Whether the atoms of an element exist individually or in groups, each element contains only one type of atom. Thus, its composition is always the same.

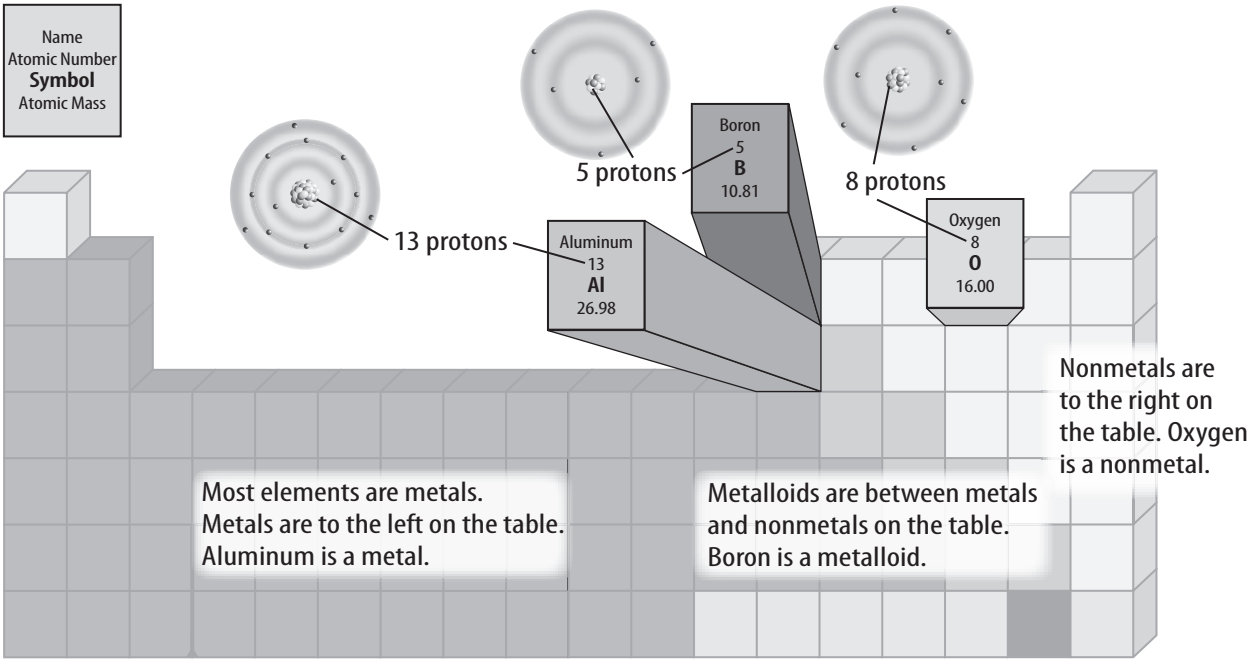
Think it Over

4. Apply Find carbon (C) on the periodic table. How many protons are in the nucleus of a carbon atom? How do you know?

Key Concept Check

5. Describe How do atoms of different elements differ?

Elements in the Periodic Table

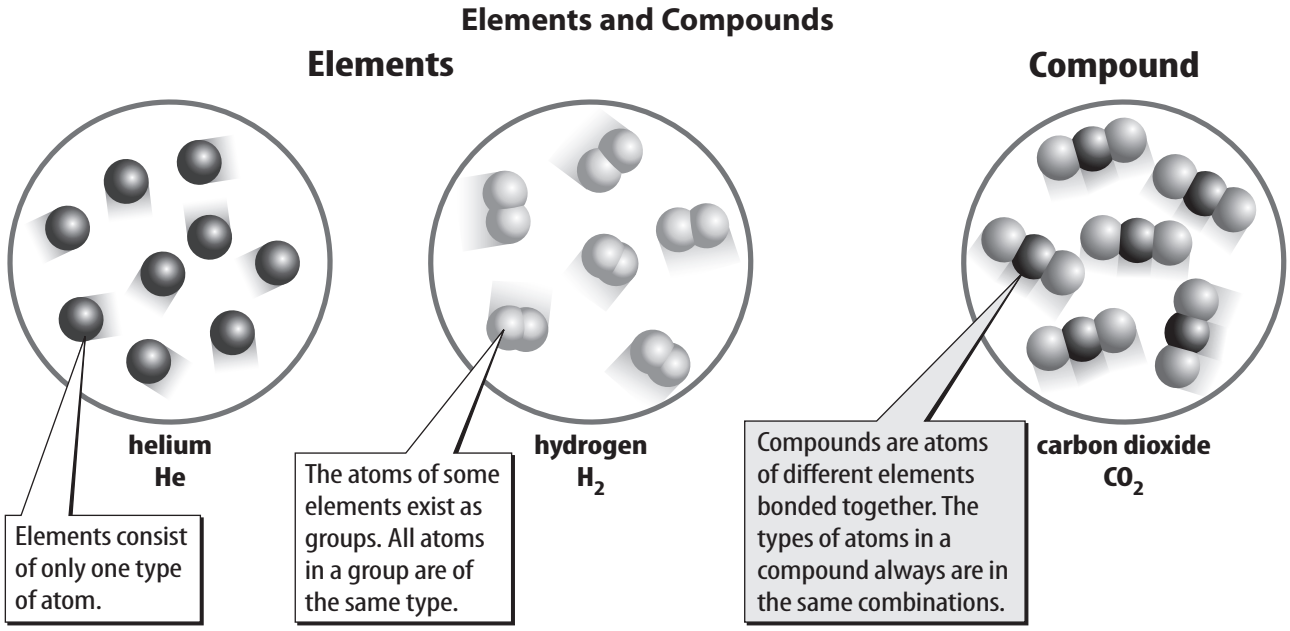


Compounds

Water is a substance, but it is not an element. It is a compound. *A* **compound** *is a type of substance containing atoms of two or more different elements chemically bonded together*. Carbon dioxide (CO_2) is also a compound. It consists of atoms of two elements, carbon (C) and oxygen (O), bonded together. Carbon dioxide is a substance because the C and the O atoms are always combined in the same way.

Visual Check

6. Contrast Which element has a higher atomic number, aluminum or oxygen?



Visual Check

7. Explain Why is CO_2 a compound but H_2 is not a compound?

The figure above contrasts elements and compounds. If a substance contains only one type of atom, it is an element. If it contains more than one type of atom, it is a compound.

Chemical Formulas A chemical formula is a combination of symbols and numbers that represent a compound. Element symbols show the different atoms that make up a compound. Chemical formulas help explain how the atoms combine. For example, the chemical formula for carbon dioxide is CO_2. The formula shows that carbon dioxide is made of C and O atoms. The small 2 is called a subscript. It means that two oxygen atoms and one carbon atom form carbon dioxide. If no subscript appears after a symbol, the compound contains only one atom of that element.

Properties of Compounds Think again about the elements carbon and oxygen. Carbon is a black solid. Oxygen is a gas that helps fuels burn. When they chemically combine, they form the compound carbon dioxide, which is a gas. A compound often has different properties from the individual elements that comprise it. Compounds, like elements, are substances that have their own unique properties.

ACADEMIC VOCABULARY

unique
(adjective) having nothing else like it

Mixtures

Mixtures are another classification of matter. *A* **mixture** *is matter that can vary in composition*. Mixtures are combinations of two or more substances that are physically blended together. The amounts of the substances can vary in different parts of a mixture and from mixture to mixture. The substances in a mixture do not combine chemically. Therefore, you can separate them by physical methods.

Heterogeneous Mixtures

Mixtures can differ by how well substances mix. Sand and water at the beach form a mixture. However, the sand is not evenly mixed throughout the water. Sand and water form a heterogeneous mixture. *A* **heterogeneous mixture** *is a type of mixture in which the individual substances are not evenly mixed*.

Because the substances in a heterogeneous mixture are not evenly mixed, two samples of the same mixture can have different amounts of the substances. For example, if you fill two buckets with sand and water at the beach, one bucket might have more sand in it than the other.

Homogeneous Mixtures

Unlike a mixture of water and sand, the substances in mixtures such as apple juice, air, or salt water are evenly mixed. *A* **homogeneous mixture** *is a type of mixture in which the individual substances are evenly mixed*. In a homogeneous mixture, the particles of individual substances are so small and well mixed that you cannot see them, even under a microscope. The table below summarizes how a homogeneous mixture differs from a heterogeneous mixture.

Think it Over

8. Apply When you pour milk on your cereal in the morning, are you making a heterogeneous mixture or a homogeneous mixture? How do you know?

Types of Mixtures

Heterogeneous Mixture	Homogeneous Mixture
• The individual substances are not evenly mixed. • Different samples of a given heterogeneous mixture can have different combinations of the same substances.	• The individual substances are evenly mixed. • Different samples of a given homogeneous mixture will have the same combinations of the same substances.

A homogeneous mixture also is called a solution. The solvent in a solution is the substance present in the largest amount. Solutes are all other substances in a solution. The solutes dissolve in the solvent. *To* **dissolve** *means to form a solution by mixing evenly*.

Because the substances in a solution, or homogeneous mixture, are evenly mixed, two samples from a solution will have the same amounts of each substance. For example, imagine pouring two glasses of apple juice from the same container. Each glass will contain the same substances (water, sugar, and other substances) in the same amounts. However, because apple juice is a mixture, the amounts of the substances might vary from one container of apple juice to another.

Visual Check

9. Distinguish Highlight the key words that distinguish a heterogeneous mixture from a homogeneous mixture.

Key Concept Check

10. Contrast How do mixtures differ from substances?

Compounds v. Solutions

If you have a glass of pure water and a glass of salt water, can you tell which is which just by looking? You cannot. The compound (water) and the solution (salt water) appear identical. How do compounds and solutions differ?

Because water is a compound, its composition does not vary. Pure water is always made up of the same atoms in the same combinations. Therefore, a chemical formula can be used to describe the atoms that make up water (H_2O). Salt water is a homogeneous mixture, or solution. The solute (NaCl) and the solvent (H_2O) are evenly mixed but are not bonded together. Adding more salt or more water only changes the relative amounts of the substances. In other words, the composition varies. Because composition can vary in a mixture, a chemical formula cannot be used to describe mixtures.

Key Concept Check

11. Classify How can you classify matter?

Summarizing Matter

You have read in this lesson about classifying matter by the arrangement of its atoms. The figure below is a summary of this classification system. Where on this diagram would you classify the things you see each day?

Visual Check

12. Identify Circle the two classifications of substances.

Classifying Matter

Matter
- Anything that has mass and takes up space
- Most matter on Earth is made up of atoms.
- Two classifications of matter: substances and mixtures

Substances
- Matter with a composition that is always the same
- Two types of substances: elements and compounds

Element
- Consists of just one type of atom
- Organized on the periodic table
- Each element has a chemical symbol.

Compound
- Two or more types of atoms bonded together
- Properties are different from the properties of the elements that make it up
- Each compound has a chemical formula.

Substances physically combine to form mixtures.

Mixtures can be separated into substances by physical methods.

Mixtures
- Matter that can vary in composition
- Substances are not bonded together.
- Two types of mixtures: heterogeneous and homogeneous

Heterogeneous Mixture
- Two or more substances unevenly mixed
- Different substances are visible by an unaided eye or a microscope.

Homogeneous Mixture—Solution
- Two or more substances evenly mixed
- Different substances cannot be seen even by a microscope.

Mini Glossary

atom: a small particle that is a building block of matter

compound: a type of substance containing atoms of two or more different elements chemically bonded together

dissolve: to form a solution by mixing evenly

element: a substance that consists of just one type of atom

heterogeneous mixture: a type of mixture in which the individual substances are not evenly mixed

homogeneous mixture: a type of mixture in which the individual substances are evenly mixed

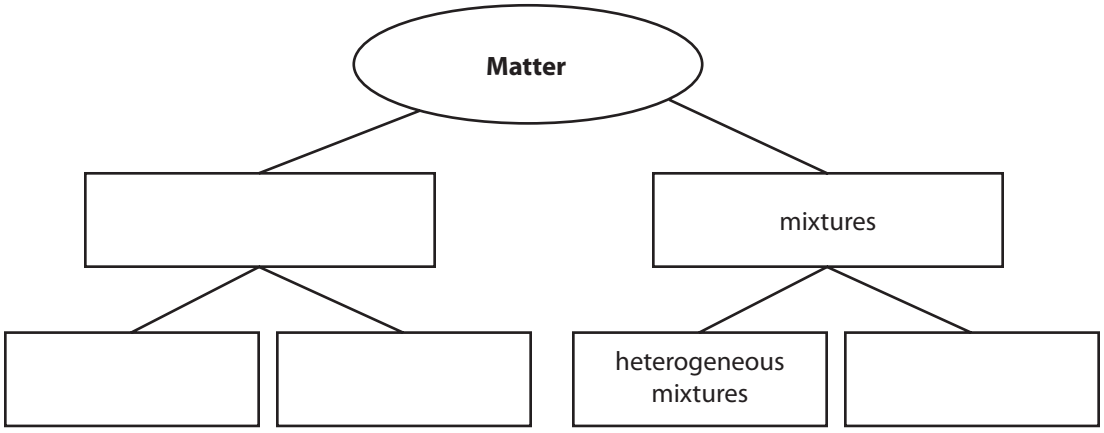
matter: anything that has mass and takes up space

mixture: matter that can vary in composition

substance: matter with a composition that is always the same

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains why light is not matter.

2. Complete the concept map by writing these terms in the correct boxes: *elements, solutions, substances, compounds*.



3. How many atoms of oxygen are in water, H_2O? Explain how you know.

What do you think NOW?

Reread the statements at the beginning of the lesson. Fill in the After column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

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END OF LESSON

Foundations of Chemistry

Physical Properties

Key Concepts

- What are some physical properties of matter?
- How are physical properties used to separate mixtures?

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	3. The weight of a material never changes, regardless of where it is.	
	4. Boiling is one method used to separate parts of a mixture.	

Read to Learn

Physical Properties

As you read in Lesson 1, the arrangement of atoms determines whether matter is a substance or a mixture. The arrangement of atoms also determines the properties of different types of matter. Each element and compound has a unique set of properties. When substances mix together and form mixtures, the properties of the substances that make up the mixture are still present.

You can observe some properties of matter. For example, you can see that gold is shiny. You can measure other properties of matter. For example, you can measure the mass of a sample of iron. Think about how you might describe the substances and mixtures in and around a flowing mountain stream. Could you describe some of the matter as a solid or a liquid? If you picked up a handful of pebbles from the bottom of the stream, why would the water leave your hand but not the pebbles? Could you describe the mass of the various rocks in the stream?

Each of these questions asks about the physical properties of matter. *A* **physical property** *is a characteristic of matter that you can observe or measure without changing the identity of the matter.* There are many types of physical properties. You will read about some types of physical properties in this lesson.

Mark the Text

Identify the Main Ideas Write a phrase beside each paragraph that summarizes the main point of the paragraph. Use the phrases to review the lesson.

REVIEW VOCABULARY

property
a characteristic used to describe something

Think it Over

1. Observe Record two physical properties of the matter around you.

States of Matter

How do aluminum, water, and air differ? Recall that aluminum is an element, water is a compound, and air is a mixture. How else do these three types of matter differ?

At room temperature, aluminum is a solid, water is a liquid, and air is a gas. Solids, liquids, and gases are called states of matter.

The state of matter is a physical property of matter. Substances and mixtures can be solids, liquids, or gases. For example, water in the ocean is a liquid, but water in an iceberg is a solid. In addition, water vapor in the air above the ocean is a gas.

The particles (atoms or groups of atoms) that make up all matter move constantly and attract each other. Your pencil is made up of trillions of moving particles.

Every solid, liquid, and gas is made up of moving particles that attract one another. The state of matter depends on how close together the particles are and how fast they move.

The particles in a solid are very close together. They can move only by vibrating back and forth. This is why solids cannot easily change shape.

The particles in a liquid are slightly farther apart than in a solid. Therefore, the particles can move past one another. This is why you can pour a liquid. The particles in a gas are farther apart. They move quickly and spread out to fill their container.

Size-Dependent Properties

State is only one of many physical properties of matter. Some physical properties, such as mass and volume, depend on the size or the amount of matter. Measurements of these properties vary depending on how much matter is in a sample.

Mass Imagine holding a small dumbbell in one hand and a larger one in your other hand. What do you notice? The larger dumbbell seems heavier. The larger dumbbell has more mass than the smaller one.

Mass *is the amount of matter in an object*. Mass is a size-dependent property of a given substance because its value depends on the size of a sample.

FOLDABLES®

Make a three-tab book to record what you learn about different states of matter.

Think it Over

2. Consider How does water vapor in the air change state below the freezing point?

Reading Check

3. Contrast How do solids, liquids, and gases differ?

Think it Over

4. Analyze Does an astronaut have more mass on Earth than in space? Why or why not?

Math Skills

When you compare two numbers by division, you are using a ratio. Density can be written as a ratio of mass and volume. What is the density of a substance if a 5-mL sample has a mass of 25 g?

a. Set up a ratio.

$$\frac{25\text{ g}}{5\text{ mL}}$$

b. Divide the numerator by the denominator to get the mass (in g) of 1 mL.

$$\frac{25\text{ g}}{5\text{ mL}} = \frac{5\text{ g}}{1\text{ mL}}$$

c. The density is 5 g/mL.

5. Use Ratios A sample of wood has a mass of 12 g and a volume of 16 mL. What is the density of the wood?

Mass and Weight An object's mass and weight are not the same. Mass is an amount of matter in something. Weight is the pull of gravity on that matter. Weight changes with location, but mass does not. Suppose a dumbbell is on the Moon. The dumbbell would have the same mass on the Moon that it has on Earth. However, the Moon's gravity is much less than Earth's gravity. As a result, the dumbbell would weigh less on the Moon than on Earth.

Volume Another physical property that depends on the size or amount of a substance is volume. A unit often used to measure volume is the milliliter (mL). Volume is the amount of space something takes up. Suppose a full bottle of water contains 400 mL of water. If you pour exactly half of the water out, the bottle contains half of the original volume, or 200 mL, of water.

Size-Independent Properties

Some physical properties of a substance do not depend on the amount of matter present. These properties are the same for small samples and large samples. They are called size-independent properties. The table below and on the next page describes several physical properties of matter. The table provides examples of how physical properties can be used to separate mixtures. Notice that conductivity, boiling and melting points, state, density, solubility, and magnetism are size-independent properties.

Melting Point and Boiling Point The temperature at which a substance changes from a solid to a liquid is its melting point. The temperature at which a substance changes from a liquid to a gas is its boiling point. Different substances have different boiling points and melting points. For example, the boiling point for water is 100°C at sea level. The boiling point does not change for different volumes of water.

Physical Properties of Matter

Property	Mass	Conductivity	Volume
Size-dependent or size-independent	size-dependent	size-independent	size-dependent
Description of property	the amount of matter in an object	the ability of matter to conduct, or carry along, electricity or heat	the amount of space something occupies
How the property is used to separate a mixture (example)	Mass typically is not used to separate a mixture.	Conductivity typically is not used to separate a mixture.	Volume could be used to separate mixtures whose parts can be separated by filtration.

Density Imagine holding a bowling ball in one hand and a foam ball of the same size in the other. The bowling ball seems heavier because the density of the material that makes up the bowling ball is greater than the density of foam. **Density** *is the mass per unit volume of a substance*. Like melting point and boiling point, density is a size-independent property.

Conductivity Another property that is independent of the sample size is conductivity. Electrical conductivity is the ability of matter to conduct, or carry along, an electric current. Copper often is used for electrical wiring because it has high electrical conductivity.

Thermal conductivity is the ability of a material to conduct thermal energy. Metals tend to have high electrical and thermal conductivity. Stainless steel, for example, often is used to make cooking pots because of its high thermal conductivity. However, the handles on the pan probably are made out of wood, plastic, or some other substance that has low thermal conductivity.

Solubility Have you ever made lemonade by stirring a powdered drink mix into water? As you stir, the powder mixes evenly in the water. In other words, the powder dissolves in the water.

What would happen if you tried to dissolve sand in water? No matter how much you stir, the sand does not dissolve. **Solubility** *is the ability of one substance to dissolve in another*. The drink powder is soluble in water, but sand is not. The table below explains how physical properties such as conductivity and solubility can be used to identify objects and separate mixtures.

Key Concept Check

6. Name What are five different physical properties of matter?

Interpreting Tables

7. Consider How might you separate a mixture of iron filings and salt?

Physical Properties of Matter

Boiling/Melting Points	State of Matter	Density	Solubility	Magnetism
size-independent	size-dependent	size-independent	size-dependent	size-independent
the temperature at which a material changes state	whether something is a solid, a liquid, or a gas	the amount of mass per unit of volume	the ability of one substance to dissolve in another	attractive force for some metals, especially iron
Each part of a mixture will boil or melt at a different temperature.	A liquid can be poured off a solid.	Objects with greater density sink in objects with less density.	Dissolve a soluble material to separate it from a material with less solubility.	Use a magnet to attract iron shavings from a mixture of metals.

Separating Mixtures

In Lesson 1, you read about different types of mixtures. Recall that the substances that make up mixtures are not held together by chemical bonds. When substances form a mixture, the properties of the individual substances do not change.

You can separate the individual substances out of most mixtures by using differences in their physical properties. For example, when salt and water form a solution, the salt and the water do not lose any of their individual properties. Therefore, you can separate the salt from the water by using differences in their physical properties. Water has a lower boiling point than salt. When you boil salt water, the water evaporates, and the salt remains.

You cannot use physical properties to separate a compound into the elements it contains. The atoms that make up a compound are bonded together and cannot be separated by physical means. For example, you cannot separate the hydrogen atoms from the oxygen atoms in water by boiling water.

Key Concept Check

8. Explain How are physical properties used to separate mixtures?

Mini Glossary

density: the mass per unit volume of a substance

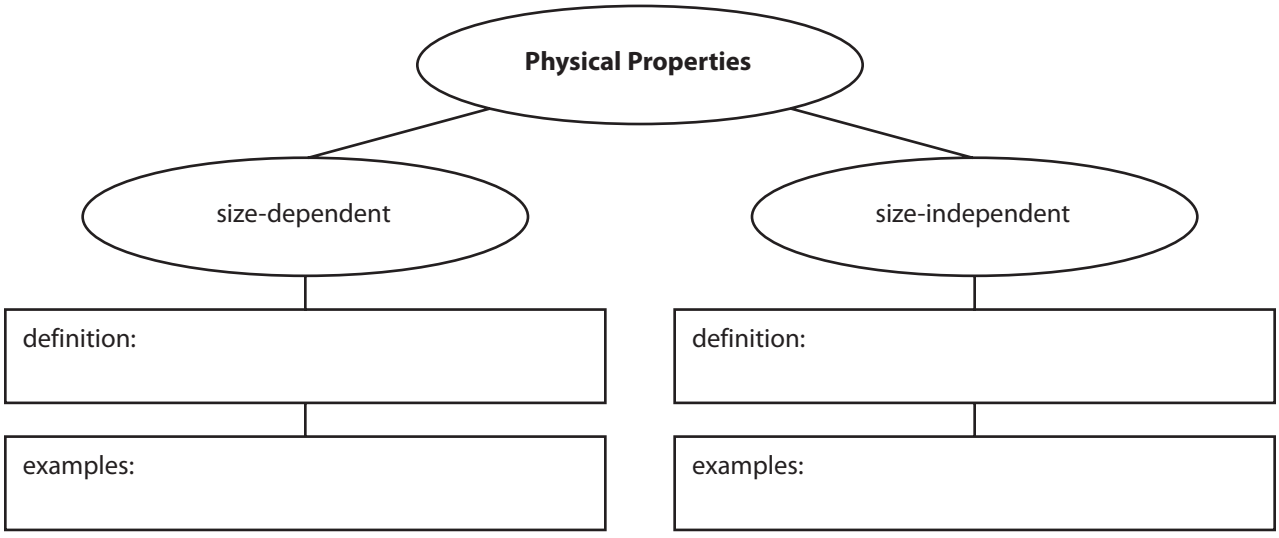
mass: the amount of matter in an object

physical property: a characteristic of matter that you can observe or measure without changing the identity of the matter

solubility: the ability of one substance to dissolve in another

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains how mass and weight are different.

2. Physical properties of matter can be classified as size-dependent or size-independent. Define each classification, and give at least two examples of each.



3. If you mix sand and water in a container, the sand will sink to the bottom. Explain why.

What do you think NOW?

Reread the statements at the beginning of the lesson. Fill in the After column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

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END OF LESSON

Foundations of Chemistry

Physical Changes

Key Concepts

- How can a change in energy affect the state of matter?
- What happens when something dissolves?
- What is meant by conservation of mass?

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

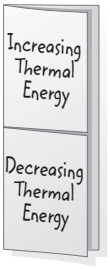
Before	Statement	After
	5. Heating a material decreases the energy of its particles.	
	6. When you stir sugar into water, the sugar and water evenly mix.	

Mark the Text

Make an Outline As you read, highlight the main idea under each heading. Then use a different color to highlight a detail or an example that might help you understand the main idea. Use your highlighted text to make an outline with which to study the lesson.

FOLDABLES®

Make a two-tab book to record specific examples of how adding or releasing thermal energy results in physical change.



Read to Learn

Physical Changes

How would you describe water? If you think about water in a stream, you might say that it is a cool liquid. If you think about water as ice, you might describe it as a cold solid. How would you describe the change from ice to water? As ice melts, some of its properties change, such as the state of matter, the shape, and the temperature. But its identity does not change. It is still water.

In Lesson 2, you read that substances and mixtures can be solids, liquids, or gases. In addition, substances and mixtures can change from one state to another. *A* **physical change** *is a change in size, shape, form, or state of matter in which the matter's identity stays the same*. During a physical change, the matter does not become something different even though physical properties change.

Change in Shape and Size

Think about changes in the shapes and the sizes of materials you experience each day. When you chew food, you are breaking it into smaller pieces. This change in size helps make food easier to digest. When you pour juice from a bottle into a glass, you are changing the shape of the juice. Changes in shape and size are physical changes. The identity of the matter has not changed.

Change in State of Matter

Why does ice melt in your hand? Or, why does water turn to ice in the freezer? Matter, such as water, can change state. Recall how the particles in a solid, a liquid, and a gas behave. To change the state of matter, the movement of the particles has to change. To change the movement of particles, thermal energy must be added or removed.

Adding Thermal Energy When thermal energy is added to a solid, the particles in the solid move faster and faster, and the temperature increases. As the particles move faster, they are more likely to overcome the attractive forces that hold them tightly together. When the particles are moving too fast for attractive forces to hold them tightly together, the solid reaches its melting point. The melting point is the temperature at which a solid changes to a liquid.

After the entire solid has melted, the addition of more thermal energy causes the particles to move even faster. The temperature of the liquid increases. When the particles are moving so fast that attractive forces cannot hold them close together, the liquid reaches its boiling point. The boiling point is the temperature at which a liquid changes into a gas and the particles spread out. Some solids change directly to a gas without first becoming a liquid. This is called sublimation.

The figure below shows what happens as thermal energy is added to a material. Temperature increases when the state of matter is not changing. Temperature stays the same during a change of state.

Think it Over

1. Analyze Why does ice melt in your hand?

_____

_____

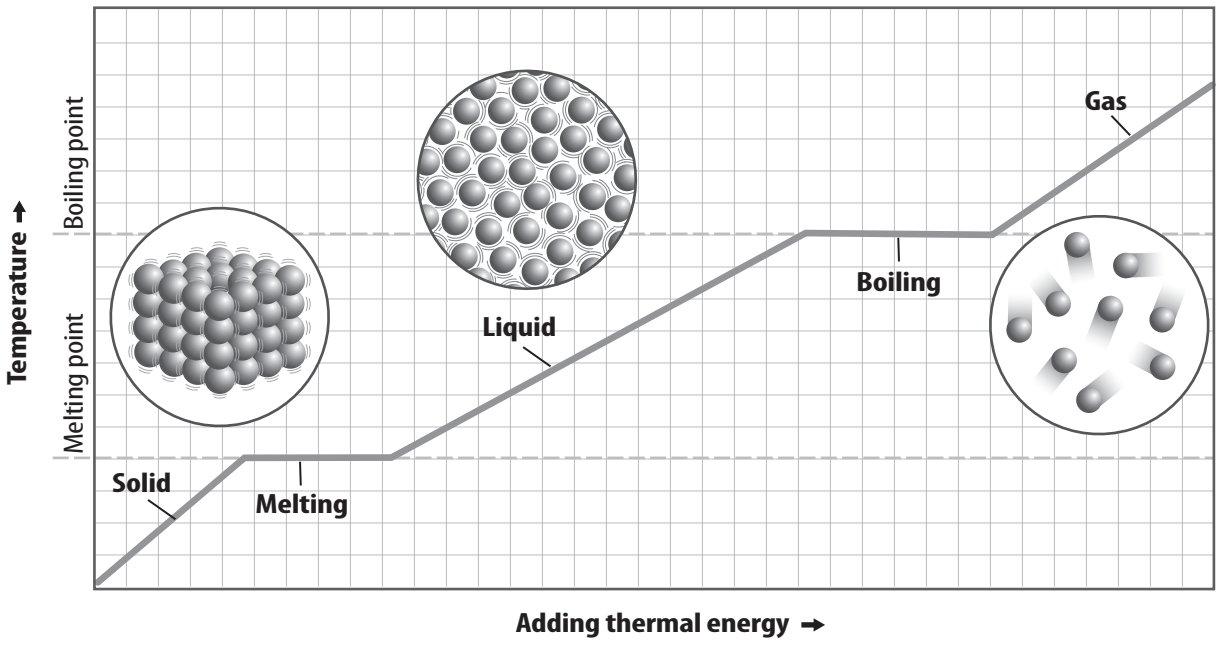
_____

_____

Visual Check

2. Point Out Circle the parts of the graph line that show a change of state is occurring.

Thermal Energy and the State of Matter



Removing Thermal Energy When thermal energy is removed from a gas such as water vapor, particles in the gas move more slowly and the temperature of the gas decreases. Condensation occurs when the particles are moving slowly enough for attractive forces to pull the particles close together. Recall that condensation is the process that occurs when a gas becomes a liquid.

After the gas has completely changed to a liquid, removing more thermal energy from the liquid causes the particles to move even more slowly. As the motion between the particles slows, the temperature decreases.

Freezing occurs when the particles are moving so slowly that attractive forces between the particles hold them tightly together. Now the particles only can vibrate in place. Recall that freezing is the process that occurs when a liquid becomes a solid.

Key Concept Check

3. Explain How can removing thermal energy affect the state of matter?

Freezing and melting are reverse processes, and they occur at the same temperature. The same is true of boiling and condensation. Another change of state is deposition. Deposition is the change from a gas directly to a solid. It is the opposite of sublimation. For example, deposition occurs when water vapor in the air forms frost.

Dissolving

Think about adding salt to water to create a saltwater aquarium. As you add the salt to the water, it gradually disappears. It is still there, but it dissolves, or mixes evenly, in the water. Because the identities of the substances—water and salt—are not changed, dissolving is a physical change.

Key Concept Check

4. Describe What happens when something dissolves?

Like many physical changes, dissolving is usually easy to reverse. If you boil the salt water, the liquid water will change to water vapor, leaving the salt behind. You once again can see the salt because the particles that make up the substances do not change identity during a physical change.

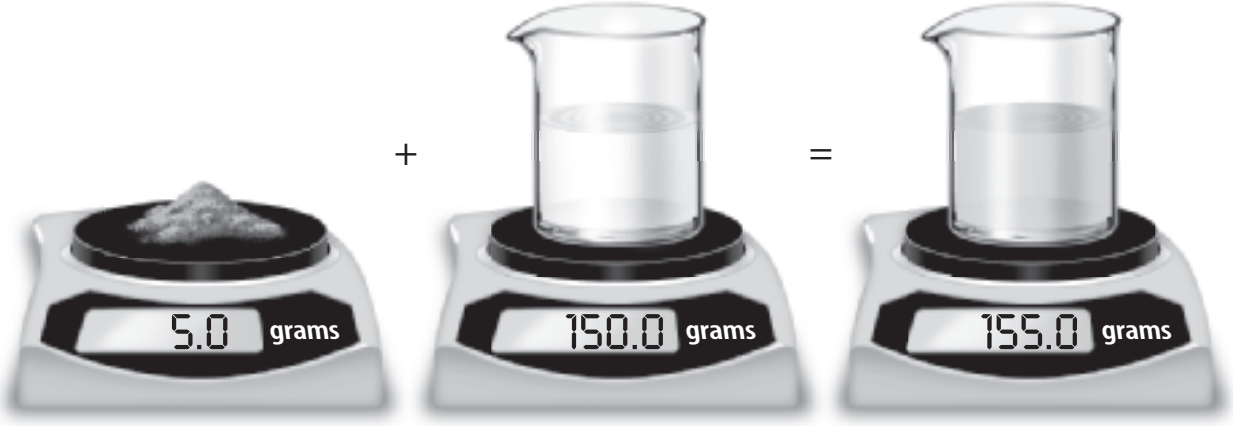
Conservation of Mass

During a physical change, the physical properties of matter change. The particles in matter that are present before a physical change are the same as those present after the physical change. Because the particles are the same before and after a physical change, the total mass before and after the change is also the same, as shown in the figure below. This is known as the conservation of mass. You will read in Lesson 4 that mass also is conserved during another type of change—a chemical change.

Key Concept Check

5. Define What is meant by conservation of mass?

Conservation of Mass



Visual Check

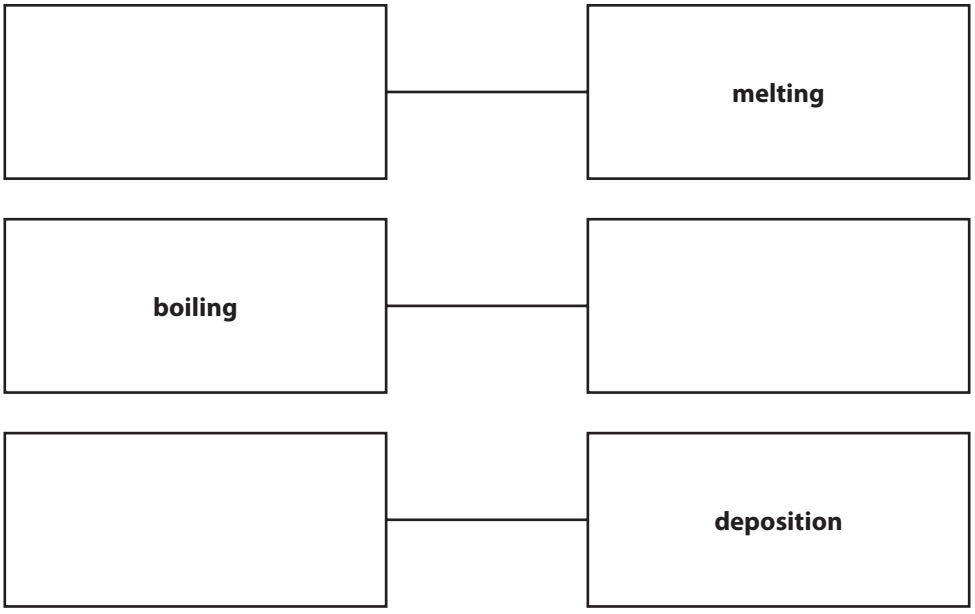
6. Calculate If a sample of water has a mass of 200 g and the final solution has a mass of 230 g, how much solute dissolved in the water?

Mini Glossary

physical change: a change in size, shape, form, or state of matter in which the matter's identity stays the same

1. Review the terms and their definitions in the Mini Glossary. Write a sentence describing something you did today that resulted in a physical change of matter.

2. For each process listed in the diagram, identify the opposite process that occurs at the same temperature.



3. How did making an outline help you learn about the physical changes of matter? Write one main point that you highlighted and an example that helped you understand the main point.

What do you think NOW?

Reread the statements at the beginning of the lesson. Fill in the After column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

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END OF LESSON

Foundations of Chemistry

Chemical Properties and Changes

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	7. When wood burns, new materials form.	
	8. Temperature can affect the rate at which chemical changes occur.	

Read to Learn

Chemical Properties

Recall that a physical property is a characteristic of matter that you can observe or measure without changing the identity of the matter. However, matter has other properties that you can observe only when the matter changes from one substance to another. *A* **chemical property** *is a characteristic of matter that can be observed as it changes to a different type of matter.* For example, can you tell by just looking at paper that it will burn easily? The only way to know that paper burns is to bring a flame near the paper and watch it burn. When paper burns, it changes into different types of matter. The ability of a substance to burn is a chemical property. The ability to rust is another chemical property.

Comparing Properties

All matter can be described by its physical and chemical properties. For example, a wood log is solid, rounded, heavy, and rough. These are physical properties that you can observe with your senses. The log also has mass, volume, and density, which are physical properties that you can measure. The ability of wood to burn is a chemical property. This property is obvious only when you burn the wood. It also will rot, another chemical property you can observe when the log decomposes, becoming other substances. When you describe matter, you consider its physical and its chemical properties.

Key Concepts

- What is a chemical property?
- What are some signs of chemical change?
- Why are chemical equations useful?
- What are some factors that affect the rate of chemical reactions?

Study Coach

Preview Headings Before you read the lesson, preview all the headings. Make a chart and write a question for each heading beginning with *What* or *How*. As you read, write the answers to your questions.

Key Concept Check

1. Identify What are some chemical properties of matter?

FOLDABLES®

Make a four-column chart to explain how the identity of matter changes during a chemical change.

Action/ Matter	Signs of Chemical Change	Explain the Chemical Reaction	What affects the reaction rate?

Chemical Changes

Recall that during a physical change, the identity of matter does not change. However, *a* **chemical change** *is a change in matter in which the substances that make up the matter change into other substances with new physical and chemical properties.* When iron undergoes a chemical change with oxygen, rust forms. The substances that undergo a change no longer have the same properties because they no longer have the same identity.

Signs of Chemical Change

How do you know when a chemical change occurs? What signs show you that new types of matter have formed? Signs of chemical changes include the formation of bubbles or a change in odor, color, or energy. For example, the odor of fruit changes when it rots. Leaves change color in autumn. Energy changes when fireworks explode.

Key Concept Check

2. Recognize What are signs of a chemical change?

These signs do not always mean a chemical change has occurred. When you heat water on a stove, bubbles form as the water boils. In this case, bubbles show that the water is changing state, which is a physical change. Bubbles that form when you add an antacid tablet to water is evidence that a chemical change might have occurred. However, the only proof of chemical change is the formation of a new substance.

Explaining Chemical Reactions

Why do chemical changes create new substances? Recall that particles in matter move constantly. As particles move, they collide with each other. If the particles collide with enough force, the bonded atoms that make up the particles can break apart. These atoms then rearrange and bond with other atoms. When atoms bond together in new combinations, new substances form. This process is called a reaction. Chemical changes often are called chemical reactions.

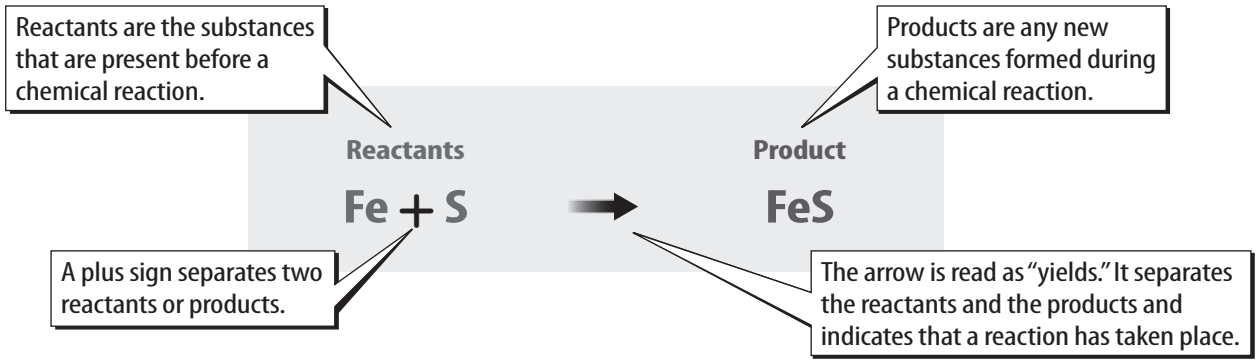
Using Chemical Formulas

A chemical equation is a useful way to express what happens during a chemical reaction. A chemical equation shows the chemical formula of each substance in the reaction. Look at the chemical equation in the figure on the next page. The formulas to the left of the arrow represent the reactants. Reactants are the substances present before the reaction takes place. The formulas to the right of the arrow represent the products. Products are the new substances present after the reaction.

Key Concept Check

3. Explain Why are chemical equations useful?

Parts of a Chemical Equation



Balancing Chemical Equations

In the equation in the figure above, notice that one iron (Fe) atom is on the reactants side and one iron atom is on the product side. This is also true for the sulfur (S) atoms. One sulfur atom is on each side of the arrow. The arrow indicates that a reaction has taken place. In a chemical equation, the arrow is read as "yields." A reaction between the reactants to the left of the arrow yields, or produces, the new products on the right side of the arrow.

Recall that during physical and chemical changes, mass is conserved. This means that the total mass before and after a change must be equal. Therefore, in a chemical equation, the number of atoms of each element before a reaction must equal the number of atoms of each element after the reaction. This is called a balanced chemical equation, and it illustrates the conservation of mass.

When balancing an equation, you cannot change the chemical formula of any reactants or products. Changing a formula changes the identity of the substance. Instead, you can place coefficients, or multipliers, in front of formulas. Coefficients change the amount of the reactants and products present.

For example, an H_2O molecule has two H atoms and one O atom. Placing the coefficient *2* before H_2O ($\mathbf{2}H_2O$) means that you double the number of H atoms and O atoms present:

$$\mathbf{2} \times 2 \text{ H atoms} = 4 \text{ H atoms}$$
$$\mathbf{2} \times 1 \text{ O atom} = 2 \text{ O atoms}$$

Note that $2H_2O$ is still water. However, it describes two water particles instead of one.

Visual Check

4. Interpret In the chemical equation above, which two substances undergo chemical changes during the reaction?

Think it Over

5. Apply Suppose you place the coefficient *4* before H_2O. How many atoms of hydrogen and how many atoms of oxygen will the formula have?

Balancing Chemical Equations

Example

When methane (CH_4)—a gas burned in furnaces—reacts with oxygen (O_2) in the air, the reaction produces carbon dioxide (CO_2) and water (H_2O). Write and balance a chemical equation for this reaction.

1. Write the equation, and check to see if it is balanced.

a. Write the chemical formulas with the reactants on the left side of the arrow and the products on the right side. **b.** Count the atoms of each element in the reactants and in the products. • Note which elements have a balanced number of atoms on each side of the equation. • If all elements are balanced, the overall equation is balanced. If not, go to step 2.	**a.** $CH_4 + O_2 \rightarrow CO_2 + H_2O$ **not balanced** **b.** reactants → products C=1 C=1 **balanced** H=4 H=2 **not balanced** O=2 O=3 **not balanced**

2. Add coefficients to the chemical formulas to balance the equation.

a. Pick an element in the equation whose atoms are not balanced, such as hydrogen. Write a coefficient in front of a reactant or a product that will balance the atoms of the chosen element in the equation. **b.** Recount the atoms of each element in the reactants and the products, and note which are balanced on each side of the equation. **c.** Repeat steps 2a and 2b until all atoms of each element in the reactants equal those in the products.	**a.** $CH_4 + O_2 \rightarrow CO_2 + \mathbf{2}H_2O$ **not balanced** **b.** C=1 C=1 **balanced** H=4 H=4 **balanced** O=2 O=4 **not balanced** **c.** $CH_4 + \mathbf{2}O_2 \rightarrow CO_2 + \mathbf{2}H_2O$ **balanced** C=1 C=1 **balanced** H=4 H=4 **balanced** O=4 O=4 **balanced**

3. Write the balanced equation that includes the coefficients: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

Interpreting Tables

6. Recognize In the table, highlight the numbers of atoms that show the equation is not balanced.

The table above explains how to write and balance a chemical equation. Equations must balance because mass does not change during a chemical reaction.

The Rate of Chemical Reactions

Recall that the particles that make up matter are constantly moving and colliding with one another. Different factors can make these particles move faster and collide harder and more frequently. These factors increase the rate of a chemical reaction.

Temperature A higher temperature usually increases the rate of reaction. For example, chemical reactions that occur during cooking happen at a faster rate when temperature increases. As temperature rises, the particles move faster. Therefore, the particles collide with greater force and more frequently.

Reading Check

7. Explain Why does the rate of reaction increase when temperature increases?

Concentration *The amount of substance in a certain volume is the* **concentration** *of the substance.* A reaction occurs faster if the concentration of at least one reactant increases. When concentration increases, more particles are available to bump into each other and react.

For example, acid rain contains a higher concentration of acid than normal rain does. As a result, a statue that is exposed to acid rain is damaged more quickly than a statue that is exposed to normal rain.

Surface Area If at least one reactant is a solid, then surface area affects reaction rate. If you drop a whole antacid tablet into water, the tablet reacts with the water. However, if you break the tablet into several pieces and then add the pieces to the water, the reaction occurs more quickly. Smaller pieces have more total surface area, so more of the broken tablet is in contact with the water. An increase in total surface area makes more surface available for reactants to collide.

Chemistry

To understand chemistry, you need to understand matter. You need to know how the arrangement of atoms results in different types of matter. You also need to be able to distinguish physical properties from chemical properties and describe ways these properties can change. In later chemistry chapters and courses, you will examine each of these topics closely to gain a better understanding of matter.

Think it Over

8. Analyze How will a decrease in the concentration of a reactant affect a chemical reaction?

_____

_____

Key Concept Check

9. Name List three factors that affect the rate of a chemical reaction.

_____

_____

_____

Mini Glossary

chemical change: a change in matter in which the substances that make up the matter change into other substances with new physical and chemical properties

chemical property: a characteristic of matter that can be observed as it changes to a different type of matter

concentration: the amount of substance in a certain volume

1. Review the terms and their definitions in the Mini Glossary. Write two sentences that explain the difference between a chemical change and a physical change.

_____

_____

_____

2. Count the number of atoms of each element on both sides of the chemical equation below. Then determine whether the equation is balanced or not balanced.

$C_2H_4O_2 + 2O_2 \longrightarrow 2CO_2 + 2H_2O$

C = _____ C = _____

H = _____ H = _____

O = _____ O = _____

balanced or not balanced? _____

3. When a banana spoils, how can you tell that a chemical change has occurred?

_____

_____

_____

What do you think NOW?

Reread the statements at the beginning of the lesson. Fill in the After column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

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END OF LESSON