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McGraw Hill Education

"Extensive knowledge and modern science must be acquired. The educational process we see today is in an ongoing and escalating challenge which requires hard work.
We succeeded in entering the third millennium, while we are more confident in ourselves."

H.H. Sheikh Khalifa Bin Zayed Al Nahyan

President of the United Arab Emirates

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Student Resources Handbook

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Science Content Background

Lesson 1

Thermal Energy, Temperature, and Heat

Thermal Energy Kinetic energy is the energy an object has because it is moving. Potential energy is stored energy. Thermal energy is the sum of the kinetic energy and the potential energy in the particles that make up a material. Mechanical energy is the sum of the potential energy and kinetic energy of an object itself. Objects can have thermal and mechanical energy at the same time.

Temperature The average kinetic energy of the particles that make up a material is its temperature. Increasing the temperature of a material increases its thermal energy, but you can increase thermal energy without increasing an object's temperature by adding potential energy. Thermometers measure temperature. Temperature scales are Fahrenheit, Celsius, and Kelvin.

Heat and Temperature Heat is the movement of thermal energy from a warmer object to a cooler object. All objects have thermal energy, but heat only occurs when thermal energy transfers from one object to another. When thermal energy moves between a material and its environment, the material's temperature changes. The rate at which heating occurs depends on the difference in temperatures between the two objects. Heating continues until all objects in contact are the same temperature.

Lesson 2

Thermal Energy Transfers

Radiation The transfer of thermal energy from one material to another by electromagnetic waves is radiation. Everything radiates thermal energy. Warmer objects radiate more thermal energy than colder objects. Radiation is the only way that the Sun's thermal energy can transfer to Earth.

Conduction The transfer of thermal energy between materials due to collisions between the particles that make up those materials is conduction. Thermal conductors are materials that easily transfer thermal energy, such as metal. Thermal insulators are materials that do not easily transfer thermal energy, such as cloth or leather.

Specific Heat The amount of thermal energy required per unit of mass to increase the temperature of a material by one degree is the material's specific heat. When a material has a low specific heat, transferring a small amount of energy to the material increases its temperature more significantly than it would an object with a high specific heat.

Thermal Expansion and Contraction Thermal expansion occurs when the amount of thermal energy in a material increases, causing the volume of the material to increase. Thermal contraction is just the opposite: It occurs when the amount of thermal energy in a material decreases, causing the volume of the material to decrease. Thermal expansion and contraction are most noticeable in gases, less noticeable in liquids, and the least noticeable in solids.

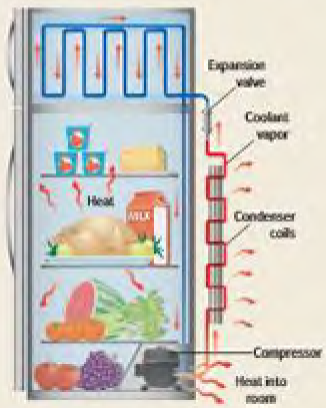
Convection The transfer of thermal energy by the movement of particles from one part of a material to another is convection. Convection only occurs in fluids because the particles that make up fluids can move easily. The movement of fluids in a cycle because of convection is called a convection current. Convection currents move air around Earth and affect Earth's climate and the locations of rain forests and deserts.

Lesson 3

Using Thermal Energy

Thermal Energy in the Home Thermal enery can be transformed into other types of energy. Heating appliances, like coffee makers, transform electrical energy into thermal energy. A thermostat regulates the temperature of a system and is part of a heating appliance. A bimetallic coil inside a thermostat tightens and loosens, causing a switch to turn a heating or cooling device on and off. A refrigerator keeps food cold by removing thermal energy from inside the refrigerator and releasing it to the surroundings.

Heat Engines A machine that converts thermal energy into mechanical energy is a hear engine, such as a car engine. A car engine transforms the chemical energy in fuel into thermal energy. Once thermal energy is converted into mechanical energy, the mechanical energy moves the vehicle. Heat engines are not efficient. Most car engines only convert about 20 percent of the chemical energy in gasoline into mechanical energy—the rest of the energy heats the car engine.



Strand Map

Required Background Knowledge

To understand the Key Concepts of this chapter, students should have the following background knowledge:

* In solids, the atoms or molecules are closely locked in position and can only vibrate. In liquids, they have higher energy, are more loosely connected, and can slide past one another. In gases, the atoms or molecules have still more energy and are free of one another except during occasional collisions.

* When warmer things are put with cooler ones, the warmer things get cooler and the cooler things get warmer until they are the same temperature.

* When warmer things are put with cooler ones, heat is transferred from the warmer ones to the cooler ones.

* A warmer object can warm a cooler one by contact or at a distance.

* When two objects are rubbed against each other, they both get warmer. In addition, many mechanical and electrical devices get warmer when they are used.

* American Association for the Advancement of Science. (1993). Benchmarks for Science Literacy. New York: Oxford University Press.

Lesson 1
Thermal Energy, Temperature, and Heat

1 The temperature of a material is the average kinetic energy of the particles that make up the material.

2 Heat is the movement of thermal energy from a warmer material to a cooler one.

Lesson 2
Thermal Energy Transfers

5 Thermal energy can be transferred through conduction, radiation, or convection.

4 When a material is heated, the thermal energy of the material increases and the material expands.

3 When a material has a low specific heat, transferring a small amount of energy to the material increases its temperature significantly.

Lesson 3
Using Thermal Energy

6 The two different metals in a bimetallic coil inside a thermostat expand and contract at different rates. The bimetallic coil curls and uncurls, depending on the thermal energy of the air, pushing a switch that turns a heating or cooling device on or off.

7 A refrigerator keeps food cold by moving thermal energy from inside the refrigerator out to the refrigerator's surroundings.

8 In a car engine, the chemical energy in fuel is transformed into thermal energy. Some of this thermal energy is then transformed into the mechanical energy.

Identifying Misconceptions

Temperature v. Thermal Energy

Find Out What Students Think

Students may think that...

... temperature is the same as thermal energy, or that thermometers measure thermal energy. Although the temperature and thermal energy are related, they are not the same thing.

Discussion

Begin clarifying the difference between temperature and thermal energy by correctly defining the two terms. Temperature represents the average kinetic energy of the particles that make up a material. Thermal energy is the sum of the kinetic energy and the potential energy in the particles that make up a material. **Ask:** In which container are the water molecules moving faster, a large pitcher of water at 50°C or a small glass of water at 100°C? How do you know? **The water molecules in the small glass of water are moving faster because the water is at a higher temperature.** **Ask:** Which container of water has more thermal energy? **Students may be unsure of the answer. Ask students to pay attention as you conduct a short experiment to find the answer.**

Promote Understanding

Activity Use this simple experiment involving the addition of hot water to cold water to demonstrate the difference between temperature and thermal energy.

1. Put 900 mL of cold water into each of two separate beakers. Measure and record the temperature of the cold water in each beaker.
2. Measure 500 mL of water at 50°C and then pour it into one of the beakers. Measure and record the temperature of the water in the beaker.
3. Measure 200 mL of water at 100°C and then pour it into the other beaker. Measure and record the temperature of the water in this beaker.
4. Explain to students that although the average water molecule in the 200 mL of water at 100°C had more energy than the average water molecule in the 500 mL of water at 50°C, the 500 mL of water at 50°C increased the temperature of the 900 mL of cold water more than the 200 mL of water at 100°C. This is because the total energy of the molecules in the 500 mL of water at 50°C was greater than the total energy of the molecules in the 200 mL of water at 100°C. The 500 mL of water at 50°C had a lower temperature, but a greater amount of thermal energy. The 200 mL of water at 100°C had a higher temperature, but a lower amount of thermal energy.

Naturally Cold?

Find Out What Students Think

Students may think that...

... some materials (such as wood or metal) are naturally colder than others.

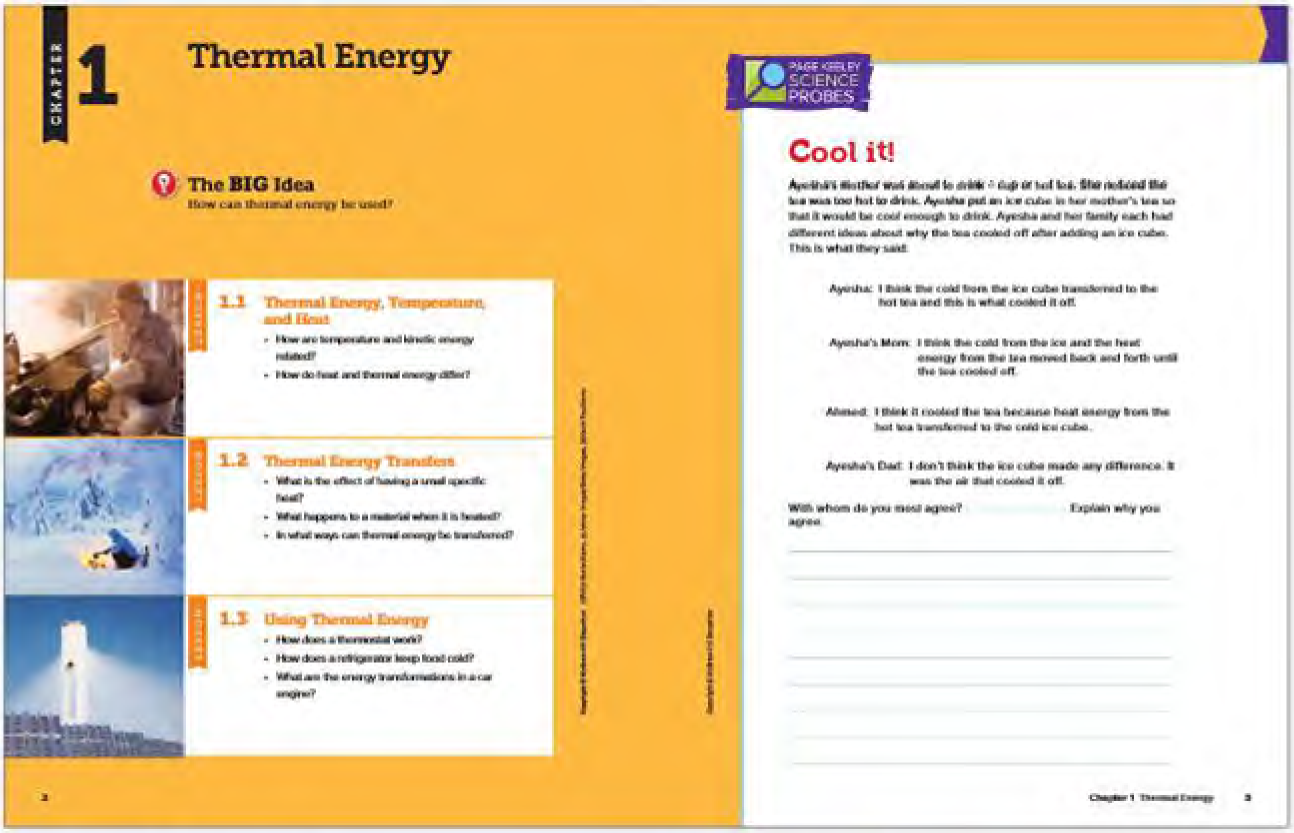
Discussion

Explain to students that at the same temperature, some materials carry thermal energy away from your hand more quickly than other materials, and this makes them feel colder. Metals carry thermal energy away more quickly than wood does. Because of this, metals usually feel colder than wood even if they are the same temperature. Materials that carry thermal energy away quickly are thermal conductors, and those that don't are thermal insulators. **Ask:** What do you think the temperature of the objects in your house would be if the thermostat of the house read 50°F? **The temperature of the objects in the house would be 50°F.** What would happen if you touched some of the objects in the house? Would they all feel the same? **No; any metal objects in the room would feel colder because metal would carry thermal energy away from your hand more quickly.**

Promote Understanding

Activity Have students place a metal object, such as a key, in their hands and ask them whether it feels warm or cool. Ask them to hold the key tightly for a short while, and then ask them how it feels. Repeat the same activity with a wooden block and have students explain what they felt. Point out that the key and the block are at the same temperature, the temperature of the room. The key feels colder than the block because the key is a thermal conductor. Thermal energy flows from your hand to the key and then is conducted away rapidly into the metal, leaving the surface of the key and your hand feeling cool. Wood, on the other hand, is a poor thermal conductor and thermal energy does not flow through it easily.

PAGE KEELEY SCIENCE PROBES


CHAPTER 1

Thermal Energy

The BIG Idea
How can thermal energy be used?

1.1 Thermal Energy, Temperature, and Heat
- How are temperature and kinetic energy related?
- How do heat and thermal energy differ?

1.2 Thermal Energy Transfers
- What is the effect of having a small specific heat?
- What happens to a material when it is heated?
- In what ways can thermal energy be transferred?

1.3 Using Thermal Energy
- How does a thermostat work?
- How does a refrigerator keep food cold?
- What are the energy transformations in a car engine?

2

PAGE KEELEY SCIENCE PROBES

Cool it!

Ayesha's mother was about to drink a cup of hot tea. She noticed the tea was too hot to drink. Ayesha put an ice cube in her mother's tea so that it would be cool enough to drink. Ayesha and her family each had different ideas about why the tea cooled off after adding an ice cube. This is what they said:

Ayesha: I think the cold from the ice cube transferred to the hot tea and this is what cooled it off.

Ayesha's Mom: I think the cold from the ice and the heat energy from the tea moved back and forth until the tea cooled off.

Ahmed: I think it cooled the tea because heat energy from the hot tea transferred to the cold ice cube.

Ayesha's Dad: I don't think the ice cube made any difference. It was the air that cooled it off.

With whom do you most agree? ______ Explain why you agree.

Chapter 1 Thermal Energy 3

Thermal Energy

The BIG Idea

There are no right or wrong answers to these questions. Write student-generated questions produced during the discussion on chart paper and return to them throughout the chapter.

Guiding Questions

AL	**What does the word *thermal* make you think of?**	*Possible answers may include: heat, temperature, thermos, and thermals.*
OL	**What types of matter emit heat?**	*Possible answers: ovens, people, sun, lamps*
EL	**Where do you think thermal energy originates?**	*Students may not be able to articulate that it is the energy within the particles of an object. They could observe that it comes from food people eat, or the electricity delivered to a lamp, or the steam emitted from boiling water.*

PAGE KEELEY SCIENCE PROBES

Cool it!

Answers to the Page Keeley Science Probe can be found in the Teacher's Edition of the *Activity Lab Workbook.*

Get Ready to Read

What do you think?

Use this anticipation guide to gauge students' background knowledge and preconceptions about thermal energy. At the end of each lesson, ask students to read and evaluate their earlier responses. Students should be encouraged to change any of their responses.

Anticipation Set for Lesson 1

1. **Temperature is the same as thermal energy.**

   Disagree. Temperature represents the average kinetic energy in a material. Thermal energy is the sum of the kinetic energy and potential energy in a material.

2. **Heat is the movement of thermal energy from a hotter object to a cooler object.**

   Agree. The definition of heat is the movement of thermal energy from a hotter object to a cooler object.

Anticipation Set for Lesson 2

3. It takes a large amount of energy to change significantly the temperature of an object with a low specific heat.

Disagree. Very little energy is necessary to significantly change the temperature of an object with a small specific heat.

4. The thermal energy of an object can never be increased or decreased.

Disagree. Thermal energy can be transferred from one object to another.

Anticipation Set for Lesson 3

5. Car engines create energy.

Disagree. Car engines transform chemical energy to thermal energy and mechanical energy; they do not create energy.

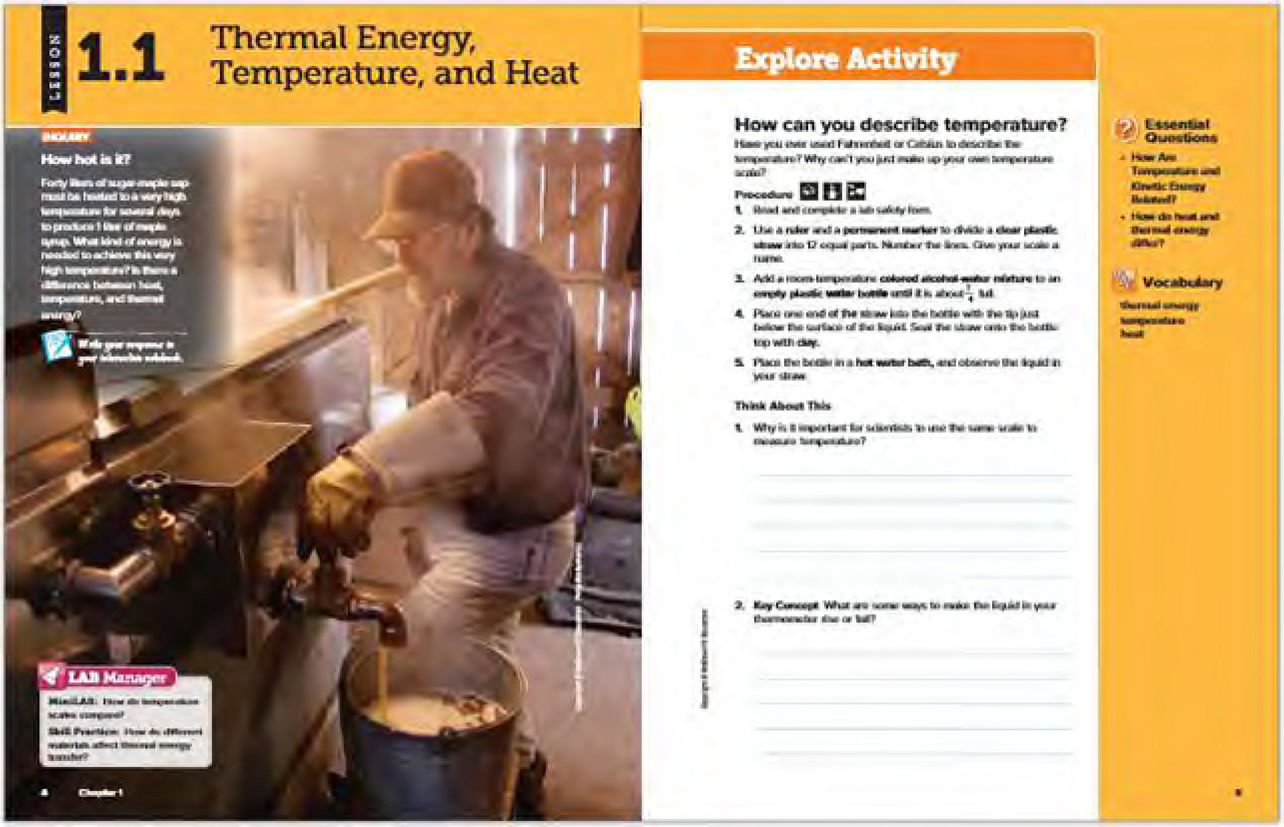
6. Refrigerators cool food by moving thermal energy from the inside of the refrigerator to the outside.

Agree. Refrigerator coolant moves thermal energy from inside to outside the refrigerator.

Options for Pre-Assessment

1. **What do you think?** Use the exercise on this page to determine your students' existing knowledge.
2. **Exam*View*® Assessment Suite** Use Exam*View*® Assessment Suite to build a pretest that covers the standards for this chapter.
3. **Concept Mapping** Have students complete the concept map in the Chapter Study Guide. Use the result to determine students' existing knowledge and areas of need.

Teacher Notes



LESSON 1.1 Thermal Energy, Temperature, and Heat

INQUIRY

How hot is it?

Forty liters of sugar-maple sap must be heated to a very high temperature for several days to produce 1 liter of maple syrup. What kind of energy is needed to achieve this very high temperature? Is there a difference between heat, temperature, and thermal energy?

Write your response in your interactive notebook.

LAB Manager

MiniLAB: How do temperature scales compare?

Skill Practice: How do different materials affect thermal energy transfer?

4 Chapter 1

Explore Activity

How can you describe temperature?

Have you ever used Fahrenheit or Celsius to describe the temperature? Why can't you just make up your own temperature scale?

Procedure

1. Read and complete a lab safety form.
2. Use a **ruler** and a **permanent marker** to divide a **clear plastic straw** into 12 equal parts. Number the lines. Give your scale a name.
3. Add a room-temperature **colored alcohol-water mixture** to an **empty plastic water bottle** until it is about $\frac{1}{4}$ full.
4. Place one end of the straw into the bottle with the tip just below the surface of the liquid. Seal the straw onto the bottle top with **clay**.
5. Place the bottle in a **hot water bath,** and observe the liquid in your straw.

Think About This

1. Why is it important for scientists to use the same scale to measure temperature?
2. **Key Concept** What are some ways to make the liquid in your thermometer rise or fall?

Essential Questions

- How Are Temperature and Kinetic Energy Related?
- How do heat and thermal energy differ?

Vocabulary

thermal energy
temperature
heat

5

INQUIRY

About the Photo How hot is it? Maple syrup is made from the sap of sugar maple trees. This sap can be tapped and then concentrated, using thermal energy. The higher the sugar concentration in the sap, the higher its boiling point. As the water evaporates from the sap, the sugar concentration increases, which increases the boiling point of the remaining liquid.

Guiding Questions

AL **What kind of energy is needed to achieve this temperature?**	*thermal energy*
OL **How are heat, temperature, and thermal energy related?**	*Heat is the movement of thermal energy from a warmer object to a cooler object. Thermal energy is the sum of the kinetic energy and potential energy in a material. Temperature represents the average internal kinetic energy in a material.*
BL **What are some things that happen to the maple sap as it is heated?**	*The kinetic energy of the particles increases, thus, temperature increases. The syrup boils and water evaporates. The syrup's sugar concentration increases and its volume decreases. The syrup's boiling point increases.*

LAB Manager

Labs can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Related Terms

1. Write the vocabulary terms on the board.
2. Ask students to read them and think about which terms or words they have heard.
3. Students are likely to be familiar with the words *temperature* and *heat*. Ask them to define both terms in their own words and to explain how they are different.

Ask: What does *thermal* mean? *The term relates to hot temperatures.*

Ask: What is energy? *Energy is the ability to cause change*

Ask: What do you think *thermal energy* means? *Energy that can cause an increase in temperature.*

Explore Activity

How can you describe temperature?

Prep: *5 min* **Class:** *15 min*

Purpose
To understand the meaning of a scale used to measure temperature.

Materials
Per student team: clear plastic straw, permanent marker, clear plastic water bottle, clay, ruler, and a 50% mixture of rubbing alcohol and water with food coloring added.

Before You Begin
Have students describe thermometers they use, such as medical, weather, oven, and lab thermometers. Note that each contains something that changes volume. This change is measured with a scale.

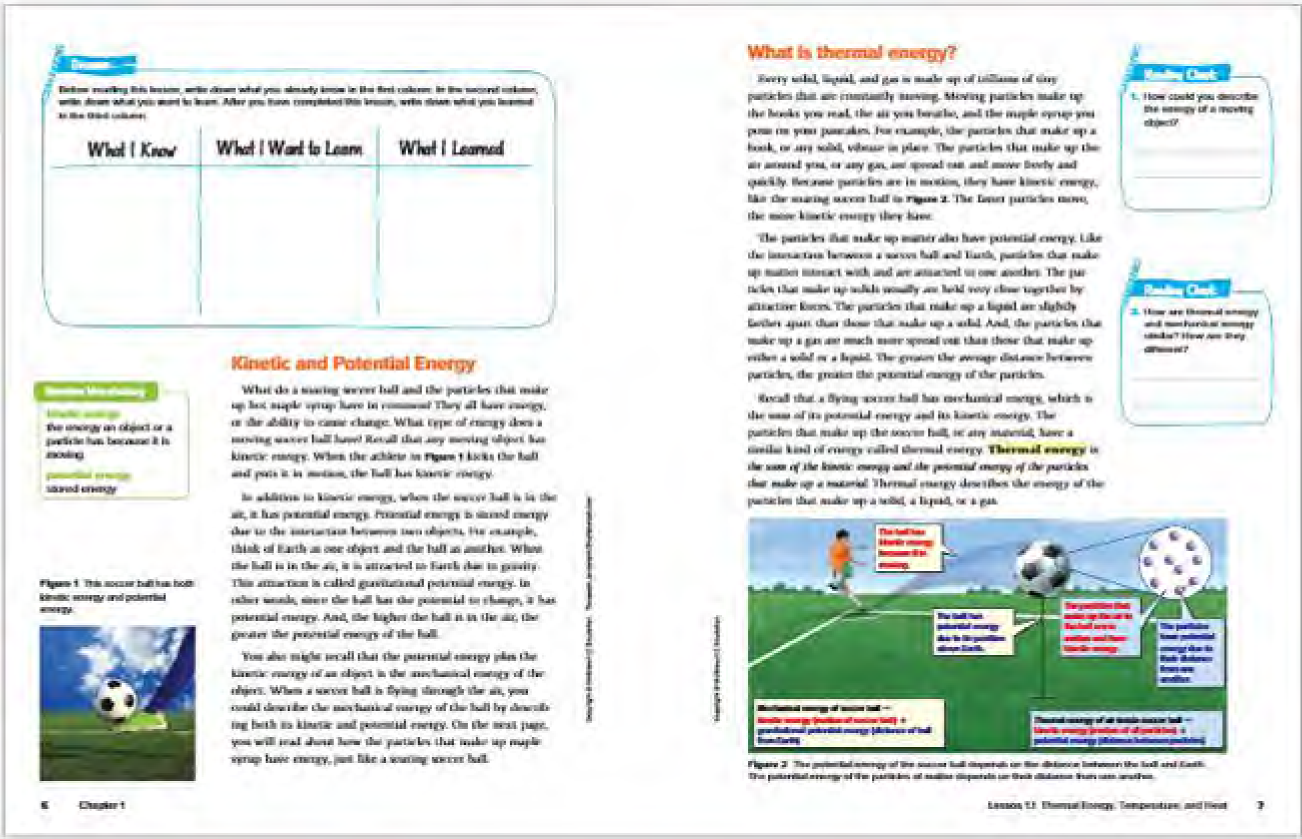
Guide the Investigation

- Caution students to press lightly on the straw so they don't crush it.
- When students test their thermometers, encourage them to think about what would happen if the liquid in the bottle were near boiling or freezing. Would their thermometer still work? Why or why not? How could they fix the problem?
- **Note:** The rise and fall of liquid in the straw is due to the expansion and contraction of the gas in the bottle, which presses on the liquid and forces it to rise in the straw.

Think About This

1. Scientists use the same scales to measure temperature so that they can accurately compare temperatures with each other.
2. **Key Concept** Possible answers: put the bottle in ice; place the bottle in a warmer or cooler room; wrap a warm cloth around the bottle

Teacher Notes



Kinetic and Potential Energy

Kinetic energy is the energy an object has due to its motion. The potential energy of an object is the energy stored in the object due to its position. An object's kinetic energy and potential energy contribute to its mechanical energy. These questions can help students understand mechanical energy.

Guiding Questions

OL **How could you describe the energy of a moving object?**	*The object has kinetic energy because it is moving. The faster the object moves, the more kinetic energy it has.*
BL **Give examples of objects with both mechanical energy and thermal energy.**	*Sample answers include cars and trains. Students should understand that particles in objects always move, so all objects have some thermal energy.*

Review Vocabulary

kinetic energy • potential energy

Ask: Can an object have kinetic and potential energy at the same time? *Yes; all objects have potential, or stored, energy. When the object moves, it also has kinetic energy.*

What is thermal energy?

Help students recall that energy is in every object because its particles are moving even if they just are vibrating in place, as in solids

The kinetic energy and potential energy of an object's particles contribute to its thermal energy. Ask these questions to guide students' understanding of thermal energy.

Guiding Questions

AL **How can we describe the potential energy of particles?**	*The potential energy is the stored energy of the particles.*
OL **How do the particles in a book falling to the ground have thermal energy?**	*The particles in the book are moving. Their kinetic energy is part of its thermal energy.*
BL **Explain what happens when a book falls in terms of its kinetic and potential energies and its particles' kinetic and potential energies.**	*The kinetic energy of the book increases because it is falling. The kinetic energy of the particles within the book remains the same. The potential, or stored, energy of the book decreases because its kinetic energy is increasing as it falls. The potential energy of the particles within the book remains the same.*

Ask: How are thermal energy and mechanical energy similar? How are they different? *They are alike because they both are the sum of kinetic energy and potential energy. However, only particles have thermal energy but objects have mechanical energy.*

Differentiated Instruction

AL **Create a Poster** Have students work in small groups to create a poster that shows as many examples of thermal energy and mechanical energy as they can think of. Students can use **Table 1** as a reference.

BL **Cooking with Energy** Have students write a paragraph about a person cooking a meal in the kitchen. In their paragraphs, ask them to describe various situations in which mechanical and thermal energy are used, such as chopping or boiling.

Teacher Toolbox

Reading Strategy

Compare/Contrast Have students write a short paragraph to compare and contrast thermal energy and temperature. They should give examples that help define each concept.

Careers in Science

Meteorologist A meteorologist is a scientist who studies the atmosphere. Meteorologists may forecast weather, research climate trends, or study how the atmosphere affects the environment. Meteorologists describe the atmosphere in terms of its temperature, pressure, wind speed, humidity, and precipitation.

Teacher Demo

Particle Motion

1. Fill a clear beaker with near boiling water. Fill another with very cold water.
2. Place two drops of red food coloring into each beaker.
3. Allow students to observe the beakers for several minutes.
4. Students should observe that the food coloring in the hot water dispersed more quickly throughout the water than the food coloring in the cold water. Explain to students that this is because the particles in the hot water have a greater average kinetic energy and move faster than the particles in the cold water.

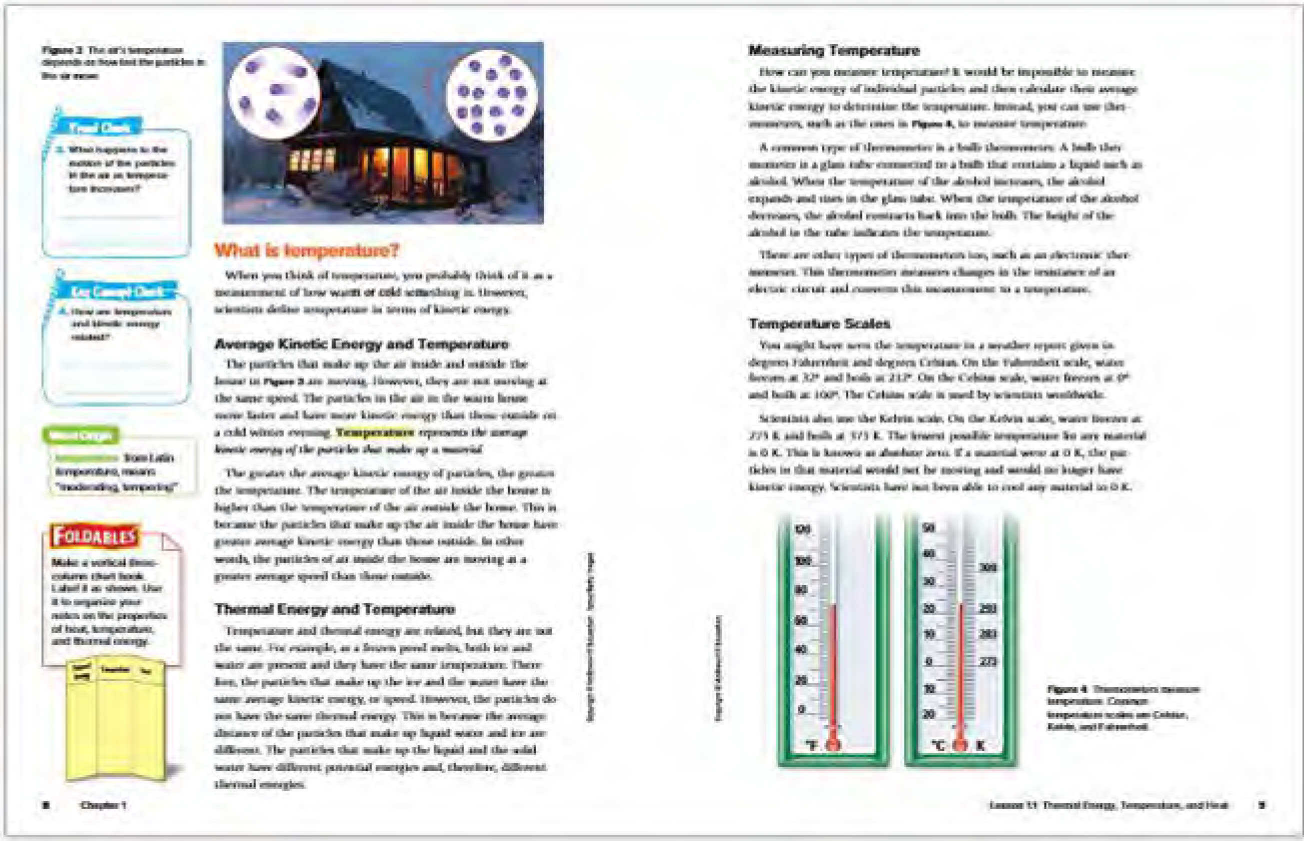


Figure 3 The air's temperature depends on how fast the particles in the air move.

What happens to the motion of the particles in the air as temperature increases?

How are temperature and kinetic energy related?

What is temperature?

When you think of temperature, you probably think of it as a measurement of how warm or cold something is. However, scientists define temperature in terms of kinetic energy.

Average Kinetic Energy and Temperature

The particles that make up the air inside and outside the house in Figure 3 are moving. However, they are not moving at the same speed. The particles in the air in the warm house move faster and have more kinetic energy than those outside on a cold winter evening. **Temperature** represents *the average kinetic energy of the particles that make up a material.*

The greater the average kinetic energy of particles, the greater the temperature. The temperature of the air inside the house is higher than the temperature of the air outside the house. This is because the particles that make up the air inside the house have greater average kinetic energy than those outside. In other words, the particles of air inside the house are moving at a greater average speed than those outside.

Thermal Energy and Temperature

Temperature and thermal energy are related, but they are not the same. For example, as a frozen pond melts, both ice and water are present and they have the same temperature. Therefore, the particles that make up the ice and the water have the same average kinetic energy, or speed. However, the particles do not have the same thermal energy. This is because the average distance of the particles that make up liquid water and ice are different. The particles that make up the liquid and the solid water have different potential energies and, therefore, different thermal energies.

Word Origin: temperature from Latin temperatura, means "moderating, tempering"

FOLDABLES: Make a vertical three-column chart book. Label it as shown. Use it to organize your notes on the properties of heat, temperature, and thermal energy.

8 Chapter 1

Measuring Temperature

How can you measure temperature? It would be impossible to measure the kinetic energy of individual particles and then calculate their average kinetic energy to determine the temperature. Instead, you can use thermometers, such as the ones in Figure 4, to measure temperature.

A common type of thermometer is a bulb thermometer. A bulb thermometer is a glass tube connected to a bulb that contains a liquid such as alcohol. When the temperature of the alcohol increases, the alcohol expands and rises in the glass tube. When the temperature of the alcohol decreases, the alcohol contracts back into the bulb. The height of the alcohol in the tube indicates the temperature.

There are other types of thermometers too, such as an electronic thermometer. This thermometer measures changes in the resistance of an electric circuit and converts this measurement to a temperature.

Temperature Scales

You might have seen the temperature in a weather report given in degrees Fahrenheit and degrees Celsius. On the Fahrenheit scale, water freezes at 32° and boils at 212°. On the Celsius scale, water freezes at 0° and boils at 100°. The Celsius scale is used by scientists worldwide.

Scientists also use the Kelvin scale. On the Kelvin scale, water freezes at 273 K and boils at 373 K. The lowest possible temperature for any material is 0 K. This is known as absolute zero. If a material were at 0 K, the particles in that material would not be moving and would no longer have kinetic energy. Scientists have not been able to cool any material to 0 K.

Figure 4 Thermometers measure temperature. Common temperature scales are Celsius, Kelvin, and Fahrenheit.

Lesson 1.1 Thermal Energy, Temperature, and Heat 9

What is temperature?

Students probably think of temperature as how hot or cold something is but may not think of it in terms of energy. Explain that every object has particles in it, and those particles always are moving. Temperature is a representation of the average kinetic energy of these particles. The faster the particles move, the greater the kinetic energy, and the higher the temperature.

Visual Literacy: Temperature

Refer students to the enlarged images of moving particles in **Figure 3**.

Ask: **What happens to the motion of the particles in the air as temperature increases?** *The motion of particles in the air increases with increasing temperatures.*

Word Origin

temperature

Ask: **The word temper can mean "to mix with something." How does this relate to the meaning of *temperature*?** *Temperature is a mixture of the kinetic energy of all the particles that make up a material.*

Ask: **The word temper can also mean "to moderate." How does this relate to the meaning of *temperature*?** *When the temperature of a material is moderated, changes occur to the kinetic energy of its particles.*

Average Kinetic Energy and Temperature

Use these questions and **Figure 2** to help students understand how temperature and kinetic energy are related. Point out that the particles in a given material do not all move at the same velocity, so it is only possible to represent the average of the particles that make up the material.

Guiding Questions

AL **If the air temperature outside is high, what does this tell you about the kinetic energy of the air particles?**	*Students should understand that high temperatures indicate high kinetic energy.*
OL **How are temperature and thermal kinetic energy related?**	*Temperature represents the average kinetic energy of the particles that make up a material.*
BL **Describe the difference between a cup of cool water and a cup of hot coffee in terms of temperature and kinetic energy.**	*A cup of cool water has a lower temperature than a cup of hot coffee, which means that the average kinetic energy of the particles of the coffee is greater than in the water.*

Thermal Energy and Temperature

Students may confuse thermal energy with temperature since both relate to the kinetic energy of particles. Use the following questions to help students to distinguish between the two.

Guiding Questions

AL **Thermal energy is the sum of what two things?**	*It is the sum of the kinetic energy and potential energy of particles.*
OL **What happens to the thermal energy in an object when you increase that object's temperature?**	*The object's thermal energy increases.*
BL **Can you increase an object's temperature without increasing its thermal energy? Explain.**	*No. Increased temperature means the average kinetic energy of an object's particles increased. Since thermal energy is the sum of kinetic and potential energies of particles, increased kinetic energy would increase thermal energy.*

Math Skills

Convert Between Temperature Scales

Point out that a change of one degree on each scale is not equivalent.

Practice

1. 30°C
2. 98.6°F

Measuring Temperature

Most students should be familiar with thermometers as a way to measure temperature, but they may need help understanding how they work. Use the following questions below to guide understanding.

Guiding Questions

AL **What do thermometers do?**	*Students should understand that thermometers measure temperature.*
OL **How does the alcohol in a bulb thermometer indicate an increase in temperature?**	*As the temperature of the alcohol increases, it expands and rises in the thermometer tube, showing an increase in temperature.*
BL **How can thermometers be calibrated by using the boiling point of water?**	*A thermometer measuring boiling water should read 212°F or 100°C.*

Visual Literacy: Figure 4

Use these questions and the thermometers in **Figure 4** to help students compare the three different temperature scales.

Ask: **On which scale does water freeze at 0° and boil at 100°?** *Celsius scale*
Ask: **What would be considered a hot summer day on the Fahrenheit, Celsius, and Kelvin scales?** *95°F, 35°C, 308 K*
Ask: **Why do you think scientists use the Kelvin scale when investigating very cold substances?** *The Kelvin scale is directly related to the average kinetic energy of substances.*

Differentiated Instruction

AL **Measuring Highs and Lows** Have students work in pairs. Ask them to find the average low and high temperatures for the previous day. Then have them convert the temperatures to Celsius and Kelvin. Students can draw three thermometers showing the equivalent temperatures on the three scales.

BL **Bad Science** Ask students to search for examples of the *terms heat* and *thermal energy* being used incorrectly. Instruct them to quote the claim, reference the source, and then explain how the term is being use incorrectly.

Teacher Toolbox

Reading Strategy

Summarize Have students reread the section entitled "What is heat?" Ask them to write a short summary to explain what the term *heat* means in a scientific sense and how it relates to temperature. Remind them that summaries should include the main ideas of a topic and supporting details.

Real-World Science

Thermal Pollution Thermal pollution is the dumping of hot water from factories and power plants into bodies of water. This causes the temperature of the water to increase, which can harm aquatic life.

Fun Fact

Reversed Scale The Celsius scale was created in 1742 by Swedish astronomer, Anders Celsius. When he first designed the scale, 0 degrees represented the boiling point of water and 100 degrees represented the freezing point of water. After Celsius died in 1744, the scale was reversed to the way we know it today.

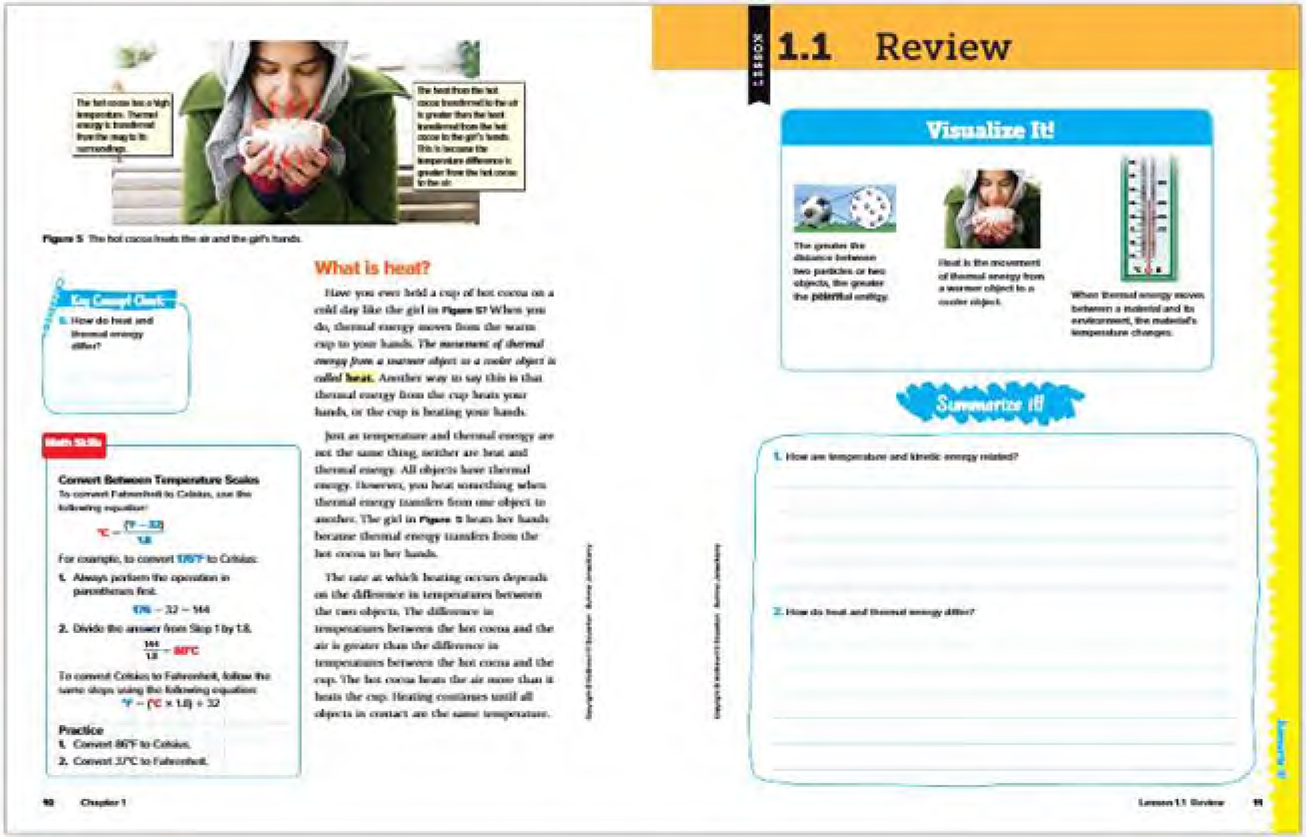


Figure 5 The hot cocoa heats the air and the girl's hands.

Key Concept Check

5. How do heat and thermal energy differ?

What is heat?

Have you ever held a cup of hot cocoa on a cold day like the girl in Figure 5? When you do, thermal energy moves from the warm cup to your hands. *The movement of thermal energy from a warmer object to a cooler object is called* **heat.** Another way to say this is that thermal energy from the cup heats your hands, or the cup is heating your hands.

Just as temperature and thermal energy are not the same thing, neither are heat and thermal energy. All objects have thermal energy. However, you heat something when thermal energy transfers from one object to another. The girl in Figure 5 heats her hands because thermal energy transfers from the hot cocoa to her hands.

The rate at which heating occurs depends on the difference in temperatures between the two objects. The difference in temperatures between the hot cocoa and the air is greater than the difference in temperatures between the hot cocoa and the cup. The hot cocoa heats the air more than it heats the cup. Heating continues until all objects in contact are the same temperature.

Math Skills

Convert Between Temperature Scales

To convert Fahrenheit to Celsius, use the following equation:

$$°C = \frac{(°F - 32)}{1.8}$$

For example, to convert 176°F to Celsius:

1. Always perform the operation in parentheses first.

$$176 - 32 = 144$$

2. Divide the answer from Step 1 by 1.8.

$$\frac{144}{1.8} = 80°C$$

To convert Celsius to Fahrenheit, follow the same steps using the following equation:

$$°F = (°C \times 1.8) + 32$$

Practice

1. Convert 86°F to Celsius.
2. Convert 37°C to Fahrenheit.

10 Chapter 1

LESSON 1.1 Review

Visualize It!

The greater the distance between two particles or two objects, the greater the potential energy.

Heat is the movement of thermal energy from a warmer object to a cooler object.

When thermal energy moves between a material and its environment, the material's temperature changes.

Summarize it!

1. How are temperature and kinetic energy related?

2. How do heat and thermal energy differ?

Lesson 1.1 Review 11

What is heat?

Use the following questions to help students understand that in science heat is the movement of thermal energy from a warmer object to a cooler object.

Guiding Questions

OL **How do heat and thermal energy differ?**	*Thermal energy is the total energy of the particles in a material. Heat is the transfer of that energy from a warmer object to a cooler object.*
BL **Describe the heat between a glass of juice at 5°C and air at 35°C.**	*Thermal energy will move from the air to the juice.*

Visual Literacy: Heat and Thermal Energy

Students may find it easier to visualize heat as the transfer of thermal energy by studying the girl and the cup in **Figure 5.**

Ask: **Why does the hot cocoa heat the air more than it heats the girl's hands?** *The temperature difference is greater between the hot cocoa and the air than between the hot cocoa and the girl's hands.*

Visual Summary

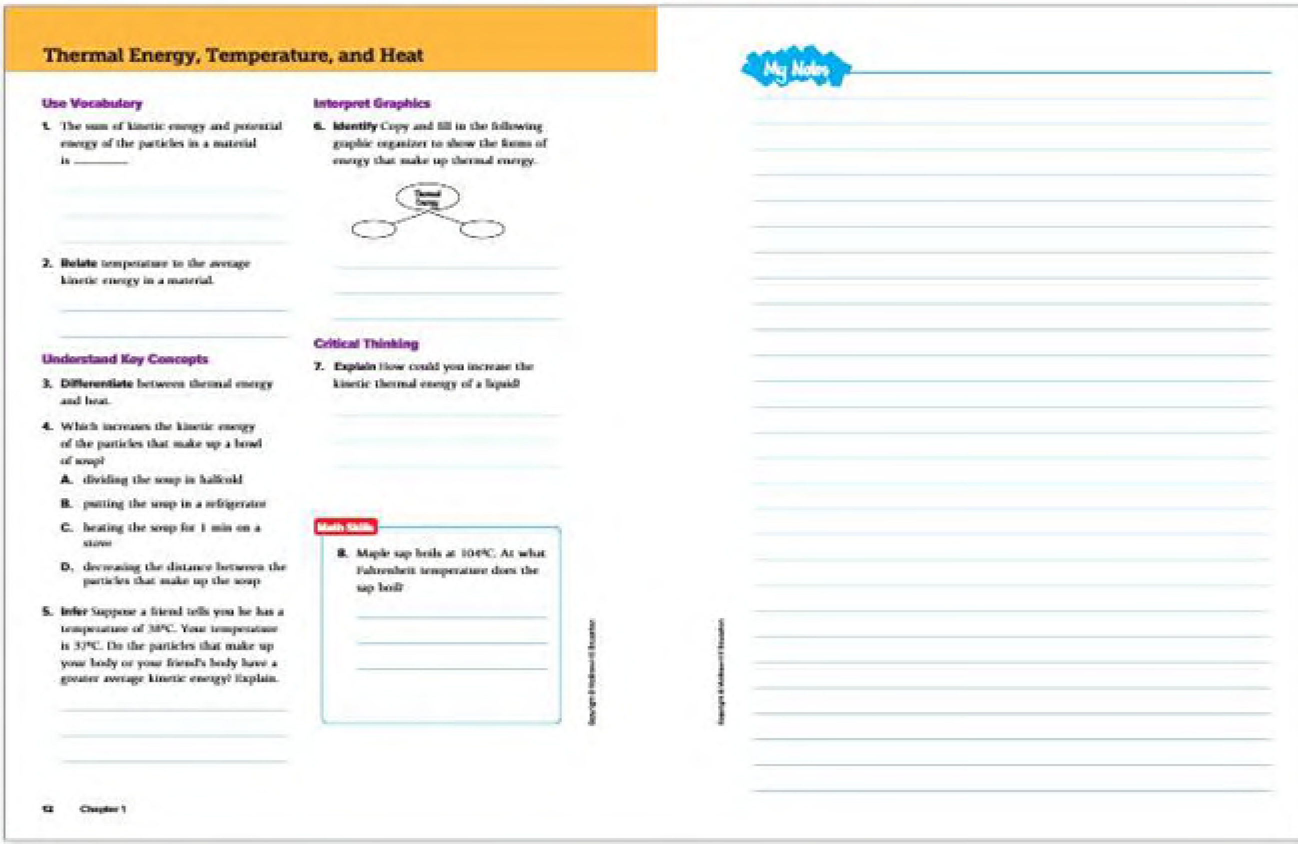
Concepts and terms are easier to remember when they are associated with an image. Ask: **To which Key Concept does each image relate?**

Summarize it!

The information needed to complete this graphic organizer can be found in the following sections:

- Kinetic and Potential Energy
- What is thermal energy?
- What is temperature?
- What is heat?

Teacher Notes



Thermal Energy, Temperature, and Heat

Use Vocabulary

1. The sum of kinetic energy and potential energy of the particles in a material is ________

2. **Relate** temperature to the average kinetic energy in a material.

Understand Key Concepts

3. **Differentiate** between thermal energy and heat.

4. Which increases the kinetic energy of the particles that make up a bowl of soup?
   - A. dividing the soup in half
   - B. putting the soup in a refrigerator
   - C. heating the soup for 1 min on a stove
   - D. decreasing the distance between the particles that make up the soup

5. **Infer** Suppose a friend tells you he has a temperature of 38°C. Your temperature is 37°C. Do the particles that make up your body or your friend's body have a greater average kinetic energy? Explain.

Interpret Graphics

6. **Identify** Copy and fill in the following graphic organizer to show the forms of energy that make up thermal energy.

Critical Thinking

7. **Explain** How could you increase the kinetic thermal energy of a liquid?

Math Skills

8. Maple sap boils at 104°C. At what Fahrenheit temperature does the sap boil?

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My Notes

Use Vocabulary

1. thermal energy
2. Temperature represents average kinetic energy of the particles in a material.

Understand Key Concepts

3. Thermal energy is the sum of the kinetic energy and potential energy of the particles in a material. Heat is the movement of thermal energy from an object that is warmer to an object that is cooler.
4. C. heating the soup for 1 min on a stove
5. The friend has a higher average kinetic energy because his temperature is greater.

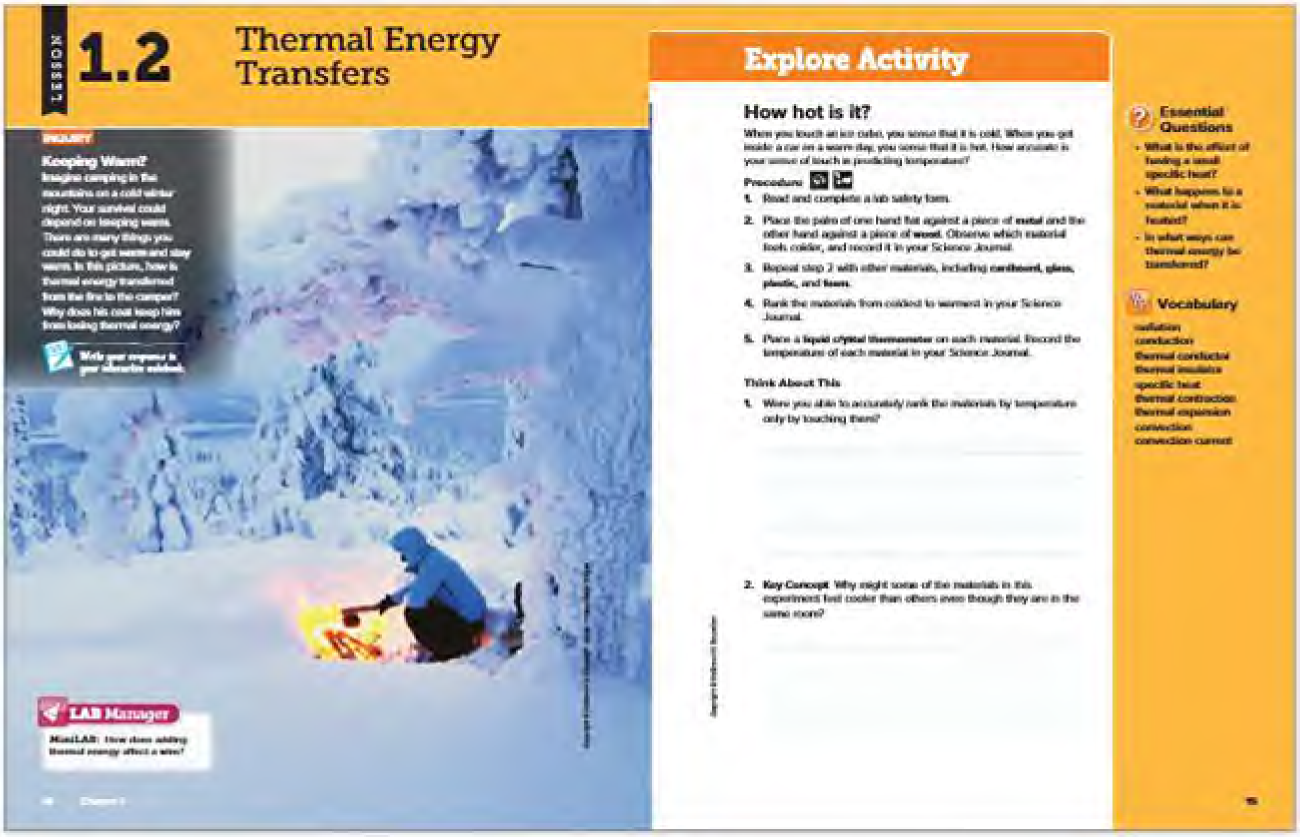
Interpret Graphics

6. Kinetic Energy, Potential Energy (in any order)
7. Raising the temperature of a liquid will increase the liquid's thermal kinetic energy.

Math Skills

8. 219.2°F

Teacher Notes



LESSON 1.2 Thermal Energy Transfers

INQUIRY

Keeping Warm? Imagine camping in the mountains on a cold winter night. Your survival could depend on keeping warm. There are many things you could do to get warm and stay warm. In this picture, how is thermal energy transferred from the fire to the camper? Why does his coat keep him from losing thermal energy?

Write your response in your interactive notebook.

LAB Manager

MiniLAB: How does adding thermal energy affect a wire?

Explore Activity

How hot is it?

When you touch an ice cube, you sense that it is cold. When you get inside a car on a warm day, you sense that it is hot. How accurate is your sense of touch in predicting temperature?

Procedure

1. Read and complete a lab safety form.
2. Place the palm of one hand flat against a piece of **metal** and the other hand against a piece of **wood**. Observe which material feels colder, and record it in your Science Journal.
3. Repeat step 2 with other materials, including **cardboard, glass, plastic,** and **foam**.
4. Rank the materials from coldest to warmest in your Science Journal.
5. Place a **liquid crystal thermometer** on each material. Record the temperature of each material in your Science Journal.

Think About This

1. Were you able to accurately rank the materials by temperature only by touching them?
2. **Key Concept** Why might some of the materials in this experiment feel cooler than others even though they are in the same room?

Essential Questions

- What is the effect of having a small specific heat?
- What happens to a material when it is heated?
- In what ways can thermal energy be transferred?

Vocabulary

radiation
conduction
thermal conductor
thermal insulator
specific heat
thermal contraction
thermal expansion
convection
convection current

INQUIRY

About the Photo **Keeping Warm?** This photo shows various thermal energy transfers. For example, convection carries the flames and smoke from the fire upward. Air around the fire heats and rises. The ground under the fire will get hot, heated by conduction. Radiation from the fire heats the camper. Use the questions below to start a discussion about thermal energy transfers and see if students can describe these transfers even they don't know the terms for them.

Guiding Questions

AL	**Where do you think the thermal energy from the fire is going?**	*Students might say into the air or into the ground.*
OL	**What will happen to the air temperature near the campfire?**	*Students should note that the temperature near the campfire will increase because thermal energy from the fire will transfer to the air.*
BL	**Explain how thermal energy is transferred in this photograph.**	*Students might mention how thermal energy from the fire transfers into the air and to the ground. Some students may know the term radiation, or they may be able to describe it.*

LAB Manager

Labs can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Brainstorm: How can thermal energy be transferred?

1. Form student groups. Have each group brainstorm various ways that thermal energy can be transferred. Try to guide the brainstorming toward examples in daily life, such as cooking or driving. Summarize all the examples by writing them down on chart paper or the board.
2. Challenge students to think of terms that describe these thermal energy transfers. Students may notice the terms in the vocabulary list and think about how some of these terms might explain the thermal energy transfers that they have come up with.

3. Then use students' examples to define the various types of thermal energy transfers that are described in this lesson, using all of the vocabulary terms.

Explore Activity

How hot is it?

Prep: *10 min* **Class:** *15 min*

Purpose
To observe the transfer of thermal energy in materials that have different specific heats.

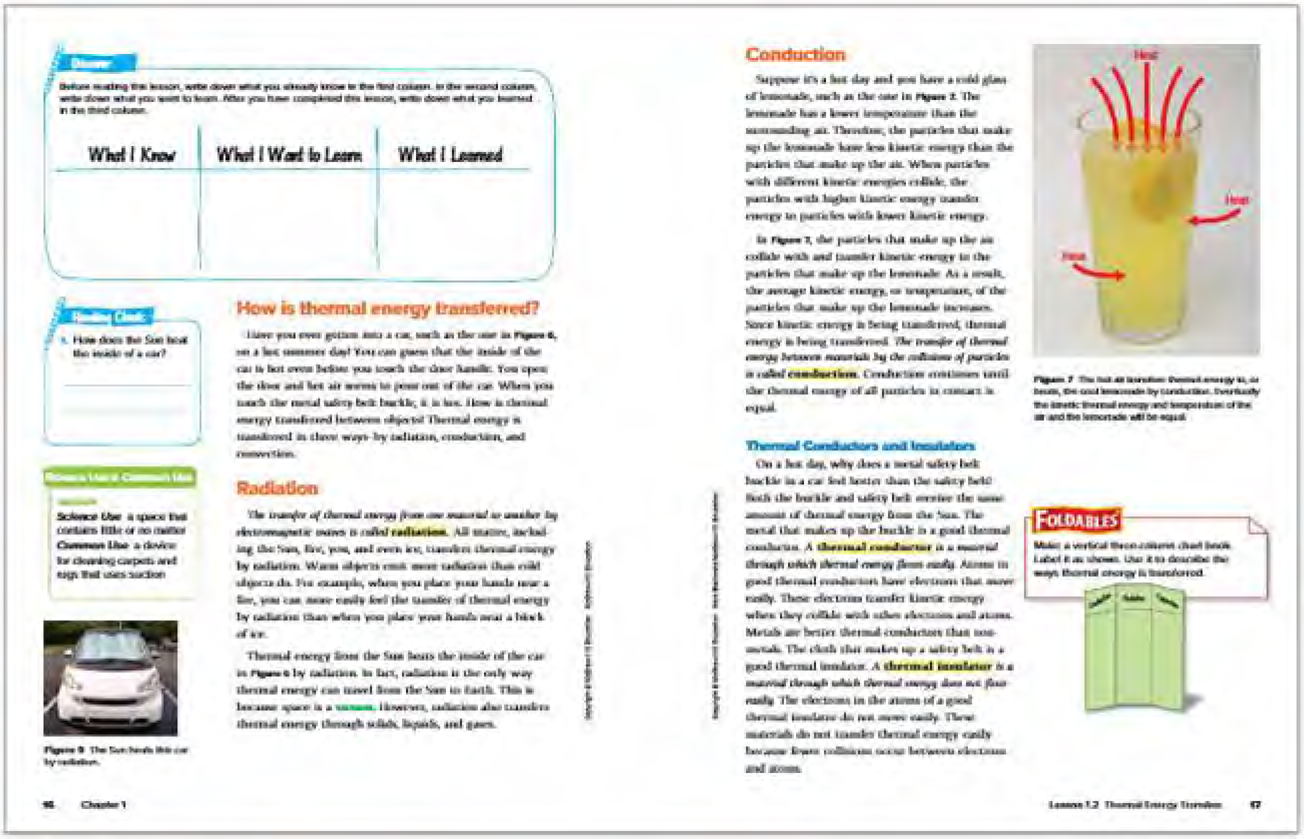
Materials
Per team: liquid crystal thermometer strips; sheets of metal, wood, foam, glass, and plastic large enough that students can place their entire hands flat on them; cardboard, each with one flat surface larger than the size of your hand

Before You Begin
- Review the use of liquid crystal thermometers to measure average kinetic energy in a solid substance.
- Material in a room should have the same temperature, even though they will feel different. If the materials are allowed to return to room temperature, they should all register the same temperature.

Guide the Investigation
- **Troubleshooting:** Metals will warm to above room temperature after a few rounds. Surfaces should be allowed to cool to room temperature for a few moments between each person's turn. It might be useful to have multiple metal samples to allow time for handled pieces to return to room temperature between uses.
- Encourage students to discuss why the materials feel different.

Think About This
1. Student answers will vary. If materials are allowed to return to room temperature, they should all be the same temperature.
2. **Key Concept** Students may speculate that thermal energy transfers from their hands to some materials more quickly than to others.

Teacher Notes



How is thermal energy transferred?

Review with students that heat is the movement of thermal energy from a warmer object to a cooler one; when an object cools, the thermal energy is not lost or destroyed but is transferred from one object to another. In this lesson, students will explore the three ways that the transfer of energy can occur.

Radiation

Students are likely familiar with the conception of radiation in relation to the Sun but may not understand how it is a transfer of thermal energy. Use these questions to help students understand this concept.

Guiding Questions

AL **What is radiation?**	*the transfer of thermal energy from one material to another by electromagnetic waves*
OL **Explain, in terms of energy, what happens when you take a cold glass of water outside on a hot day.**	*Thermal energy from the Sun, in the form of radiation, and thermal energy from the air transfers by conduction into the glass of water.*
BL **Why can wearing black clothing on a hot day make you feel hotter?**	*Students may know that the color black absorbs the most radiation from the Sun; therefore, they will feel hotter in black clothing.*

Conduction

Students are probably familiar with the concept of conduction even if the term is unfamiliar. Remind students that heat is the transfer of thermal energy from a warmer object to a cooler object. As an object is heated, its particles move faster. As they do, they collide and transfer thermal energy until all particles are warmer. Use these questions about a cup of hot tea to help students understand these concepts.

Guiding Questions

AL **Describe how a cup of hot tea cools in terms of conduction.**	*Due to conduction, the particles in the tea transfer thermal energy to the cooler air, cooling the tea. Thermal energy from the tea is also conducted into the cup.*
OL **How is a cold glass of lemonade warmed by warm air?**	*The faster-moving air particles collide with the slower-moving lemonade particles, giving them greater thermal kinetic energy.*
BL **Why would a cup of hot tea with a metal spoon in it cool down faster than a cup of hot tea without a metal spoon?**	*Because a cup of hot tea with a spoon in it has more surface area in contact with the cooler air than a cup without a spoon, and thermal energy transfer can occur more rapidly.*

Thermal Conductors and Insulators

Use the following questions to help students understand the concept of thermal insulators and conductors in terms of objects with which they may be familiar.

Guiding Questions

AL **What would happen on a hot day if seatbelts were made of metal instead of cloth?**	*The seatbelts would be very hot because metal is a good thermal conductor and would absorb the heat from sunlight very quickly.*
OL **Why are cooking pots and pans usually made of metals?**	*Metals are better thermal conductors than nonmetals. They are able to quickly transfer thermal energy from the stove burner into the contents of the pots and pans.*
BL **What are some household appliances that use both thermal conductors and thermal insulators?**	*The barrel of a curling iron is made of metal while the handle is made of plastic. A toaster has metal wire inside, while the outside is made of plastic.*

Differentiated Instruction

AL **Write a Short Skit** Have groups of students write a short skit that involves thermal insulators and conductors. Students should think of scenarios in which they might experience a thermal insulator or thermal conductor and what might happen.

BL **Create a Comic Book** Have students create a comic book that features a story involving thermal insulators and conductors. Encourage students to think of ways that people might interact with different types of materials and what their reactions might be.

Teacher Toolbox

Reading Strategy

Main Idea and Details Have students list the main idea of each paragraph in the lesson. Then for each main idea, have them list at least two details to support it. Students should try to use at least one word from the vocabulary list in their main ideas or details.

Teacher Demo

The Best Thermal Conductor Place various long, slim items such as metal cutlery, wood, and plastic sticks into a mug. Place a drop of candle wax onto the upper ends of each item. Pour near boiling water into the mug. As each substance conducts the heat upward, the wax will melt. Have students observe which substance is the best thermal conductor.

Real-World Science

How does a thermos know? How does a thermos know whether the fluid inside it is hot or cold? It doesn't. A thermos is a thermal insulator, decreasing the heat transfer between its walls. This lets the fluid inside the thermos remain at the same temperature for a long period of time whether hot or cold.

Specific Heat

The amount of thermal energy required to increase the temperature of 1 kg of a material by 1°C is called **specific heat.** Every material has a specific heat. It does not take much energy to change the temperature of a material with a low specific heat but it can take a lot of energy to change the temperature of a material with high specific heat.

Thermal conductors, such as the metal safety-belt buckle in **Figure 8**, have a lower specific heat than thermal insulators, such as the cloth safety belt. This means it takes less thermal energy to increase the buckle's temperature than it takes to increase the temperature of the cloth safety belt by the same amount.

The specific heat of water is particularly high. It takes a large amount of energy to increase the temperature of water. The high specific heat of water has many beneficial effects. For example, much of your body is water. Water's high specific heat helps prevent your body from overheating. The high specific heat of water is one of the reasons why pools, lakes, and oceans stay cool in summer. Water's high specific heat also makes it ideal for cooling machinery, such as car engines and rock-cutting saws.

Key Concept Check

2. What does it mean if a material has a low specific heat?

Academic Vocabulary

specific

(adjective) precise and detailed; belonging to a distinct category

Figure 8 On a hot summer day, the air in the car is hot. The temperature of thermal conductors, such as the safety-belt buckles, increases more quickly than the temperature of thermal insulators, such as the seat material.

Thermal Expansion and Contraction

What happens if you take an inflated balloon outside on a cold day? Thermal energy transfers from the particles that make up the air inside the balloon to the particles that make up the balloon material and then to the cold outside air. As the particles that make up the air in the balloon lose thermal energy, which includes kinetic energy, they slow down and get closer together. This causes the volume of the balloon to decrease. **Thermal contraction** *is a decrease in a material's volume when its temperature decreases.*

How could you reinflate the balloon? You could heat the air inside the balloon with a hair dryer, like in **Figure 9**. The particles that make up the hot air coming out of the hair dryer transfer thermal energy, which includes kinetic energy, to the particles that make up the air inside the balloon. As the average kinetic energy of the particles increases, the air temperature increases. Also, as the average kinetic energy of the particles increases, they speed up and spread out, increasing the volume of air inside the balloon. **Thermal expansion** *is an increase in a material's volume when its temperature increases.*

Thermal expansion and contraction are most noticeable in gases, less noticeable in liquids, and the least noticeable in solids.

Figure 9 Air inside the balloon increases in volume when the temperature increases.

Figure 10 Sidewalks can withstand thermal expansion and contraction because of control joints.

Key Concept Check

3. What happens to the volume of a gas when it is heated?

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Specific Heat

An object with a high specific heat requires more thermal energy to increase its temperature than an object with a low specific heat. Thermal conductors have a lower specific heat than thermal insulators.

Guiding Questions

AL **What is the specific heat of a material?**	*It is the amount of thermal energy required to increase the temperature of 1 kg of that material 1 degree Celsius.*
OL **What does it mean if a material has a low specific heat?**	*It takes less thermal energy to increase its temperature than it would for a material with a higher specific heat.*
BL **Why would it be helpful to know the specific heat of a material?**	*It could tell you whether the material would be a good thermal insulator or conductor.*

Visual Literacy: Specific Heat

Use **Figure 8** and the following questions to relate specific heat to thermal conductors and insulators, and to clarify the differences between the two.

Ask: **Which objects in the car are thermal insulators?** *The seat material and the seatbelts.* **Which objects are thermal conductors?** *The metal seat buckle and the metal gear shift.* **Ask:** **How do you know that cloth has a higher specific heat than metal?** *Cloth is a not a good thermal conductor and therefore, does not conduct heat as easily as metal. Metal has a lower specific heat than cloth.*

Academic Vocabulary

specific

Have students use the word *specific* in a nonscience context. *Possible answer: The restaurant patron was specific about how she wanted her order.*

Thermal Expansion and Contraction

Review conduction and radiation by asking students why thermal energy transferred from the hair dryer to the balloon was by convection while thermal energy transferred from the balloon to the air inside by conduction. Use these questions and the illustrations in **Figure 8** to help explain the concepts of thermal expansion and contraction.

Guiding Questions

OL **What happens to the amount of thermal energy in a material during thermal expansion and during thermal contraction?**	*During thermal expansion, thermal energy in a material increases. During thermal contraction, thermal energy in a material decreases.*
BL **What happens to the volume of a gas when it is heated?**	*The volume increases.*
BL **How do bulb thermometers demonstrate thermal expansion**	*As the temperature of the liquid in the thermometer bulb increases, the liquid expands, increasing its volume, and the liquid rises in the thermometer.*

Sidewalk Gaps

Students are probably familiar with gaps in sidewalks. Use the following questions to help students understand why gaps intentionally are placed in sidewalks to account for thermal expansion. Facilitate a discussion with students about other places where thermal expansion can be observed. Ask students if they have ever had difficulty removing the lid from a jar but after running hot water over the lid, they were then able to open the jar. Explain that the hot water causes the metal lid to expand, but the glass jar does not expand at the same rate. Also, most large bridges have expansion joints. These provide room for the bridge to expand and contract in response to temperature changes. Explain that in this chapter they will explore other places where thermal expansion can be observed.

Guiding Questions

AL **What can cause thermal expansion in sidewalks?**	*Heating causes the thermal energy in the sidewalk to increase, which increases its volume.*
OL **What would happen if there were no gaps between sections of sidewalks?**	*The sidewalks would expand and crack.*
BL **How can a door that sticks in the summertime be explained by thermal expansion?**	*The thermal energy in the door increases, which increases its volume, and it expands past where it usually fit in the doorway.*

Differentiated Instruction

AL **Draw a Labeled Balloon** Have students reread the section on hot air balloons. Then have them create a labeled diagram of a hot air balloon with arrows showing what is happening to the air and the terms *thermal expansion* and *thermal contraction*.

BL **More Examples** Have students brainstorm other real life examples of thermal expansion and thermal contraction. They can do research or they can discuss their ideas in groups. Students should create a list of these examples with explanations for each.

Teacher Toolbox

Fun Fact

Boiling Balloons Hot air balloons are not flown in the rain. This is because the air inside the balloon is so hot that it can cause the water on top of the balloon to boil. The boiling water would ruin the fabric of the balloon.

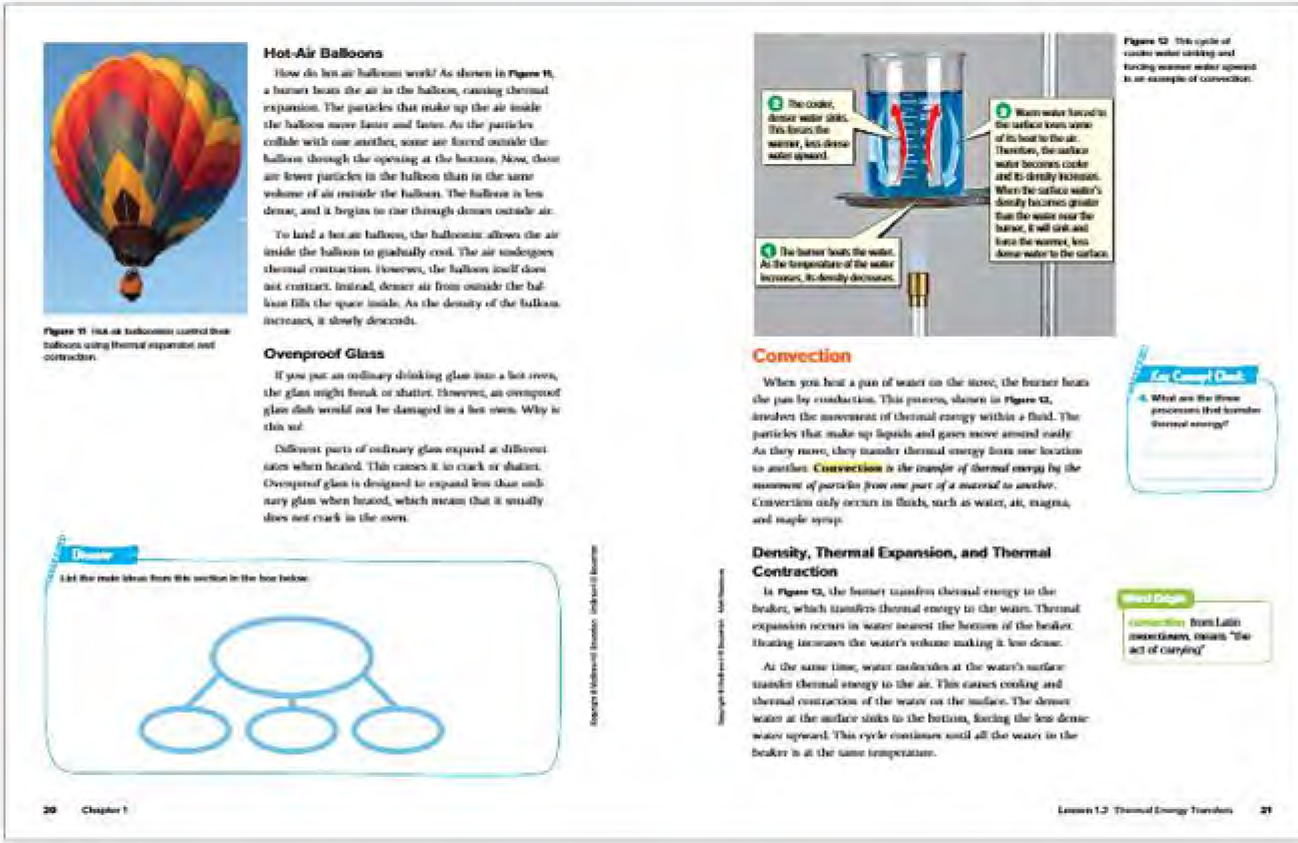
Teacher Demo

Expanding Straw Use a straw to poke a hole in a flat piece of extruded polystyrene foam. Then remove the straw and place half of it into boiling water for about 20 seconds. Ask a volunteer to put the straw back into the hole. The straw will not fit now because of thermal expansion—the heat of the boiling water caused the particles in the straw to move faster, which increased the straw's volume.

Real-World Science

Expanding Gasoline When gasoline comes from the underground tank at the gas station, it is cool, but it warms in the tank of a car. If a car's gas tank is filled and then left to sit in the sun, the gasoline may expand faster than the car's fuel tank, and it can overflow onto the ground.

OL On Level AL Approaching Level BL Beyond Level



Hot-Air Balloons

How do hot-air balloons work? As shown in **Figure 11**, a burner heats the air in the balloon, causing thermal expansion. The particles that make up the air inside the balloon move faster and faster. As the particles collide with one another, some are forced outside the balloon through the opening at the bottom. Now, there are fewer particles in the balloon than in the same volume of air outside the balloon. The balloon is less dense, and it begins to rise through denser outside air.

To land a hot-air balloon, the balloonist allows the air inside the balloon to gradually cool. The air undergoes thermal contraction. However, the balloon itself does not contract. Instead, denser air from outside the balloon fills the space inside. As the density of the balloon increases, it slowly descends.

Figure 11 Hot-air balloonists control their balloons using thermal expansion and contraction.

Ovenproof Glass

If you put an ordinary drinking glass into a hot oven, the glass might break or shatter. However, an ovenproof glass dish would not be damaged in a hot oven. Why is this so?

Different parts of ordinary glass expand at different rates when heated. This causes it to crack or shatter. Ovenproof glass is designed to expand less than ordinary glass when heated, which means that it usually does not crack in the oven.

Discover

List the main ideas from this section in the box below.

20 Chapter 1

Figure 12 This cycle of cooler water sinking and forcing warmer water upward is an example of convection.

Convection

When you heat a pan of water on the stove, the burner heats the pan by conduction. This process, shown in **Figure 12**, involves the movement of thermal energy within a fluid. The particles that make up liquids and gases move around easily. As they move, they transfer thermal energy from one location to another. **Convection** *is the transfer of thermal energy by the movement of particles from one part of a material to another.* Convection only occurs in fluids, such as water, air, magma, and maple syrup.

Key Concept Check

4. What are the three processes that transfer thermal energy?

Density, Thermal Expansion, and Thermal Contraction

In **Figure 12**, the burner transfers thermal energy to the beaker, which transfers thermal energy to the water. Thermal expansion occurs in water nearest the bottom of the beaker. Heating increases the water's volume making it less dense.

At the same time, water molecules at the water's surface transfer thermal energy to the air. This causes cooling and thermal contraction of the water on the surface. The denser water at the surface sinks to the bottom, forcing the less dense water upward. This cycle continues until all the water in the beaker is at the same temperature.

Word Origin

convection from Latin convectionem, means "the act of carrying"

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Hot Air Balloons

Use the following questions and **Figure 10** to help students understand how thermal expansion and contraction help hot air balloons work.

Guiding Questions

AL **What causes the initial thermal expansion in a hot air balloon?**	*A burner heating the air in the balloon.*
BL **Why do you think larger hot air balloons can rise higher than smaller ones?**	*A larger balloon can have a lower density than a smaller balloon which would make it more buoyant and easier to rise.*

Ovenproof Glass

Explain to students that glass expands very quickly when heated, which can cause it to shatter. To make glass ovenproof, its chemical composition is changed.

Guiding Questions

OL **Describe what can happen to glass in an oven in terms of thermal energy.**	*Heating the glass can cause the thermal energy in the glass to increase, which would increase its volume and make it crack.*
BL **How can putting a hot liquid into a very cold glass cause the glass to break?**	*The thermal energy from the liquid quickly transfers to the cold glass, which can cause the inside of the glass to expand more quickly than the outside of the glass and break.*

Convection

Students might confuse the term *convection* with *conduction* since the two terms sound similar and the function of both is to transfer thermal energy. Explain that conduction occurs between two materials, whereas convection occurs within a material and only in fluids.

Guiding Questions

AL **What happens during convection?**	*Warm liquid from one place moves to another place, which transfers thermal energy.*
OL **What are three processes that transfer thermal energy?**	*radiation, conduction, convection*
BL **Why can convection only take place in liquids or gases and not in solids?**	*Convection can take place in liquids and gases because their particles move around easily, but the particles in solids do not move around.*

Word Origin

convection

Ask: How does "carrying" relate to the meaning of convection? *When convection occurs, particles are "carried" from one part of a material to another.*

Visual Literacy: Sample of Convection

Ask these questions to help students analyze the convection illustration in **Figure 12** and to assess their understanding.

Ask: What do the color and direction of the arrows indicate? *The red arrows indicate the upward movement of heated, less dense water. The blue arrows indicate the downward movement of cooler, denser water.*

Ask: When will the convection cycle of rising and sinking end? *when all the water is the same temperature*

Differentiated Instruction

AL **Draw a Convection Current** Have students draw a diagram that shows what happens as hot water is poured into a pitcher of cold water. Students should label the diagram, including the terms *thermal energy, density, temperature,* and *heat.*

BL **Write a Weather Report** Using the details in **Figure 12** have students write a weather report that involves convection currents and its effects on the weather. Students can do additional research to help with details.

Teacher Toolbox

Reading Strategy

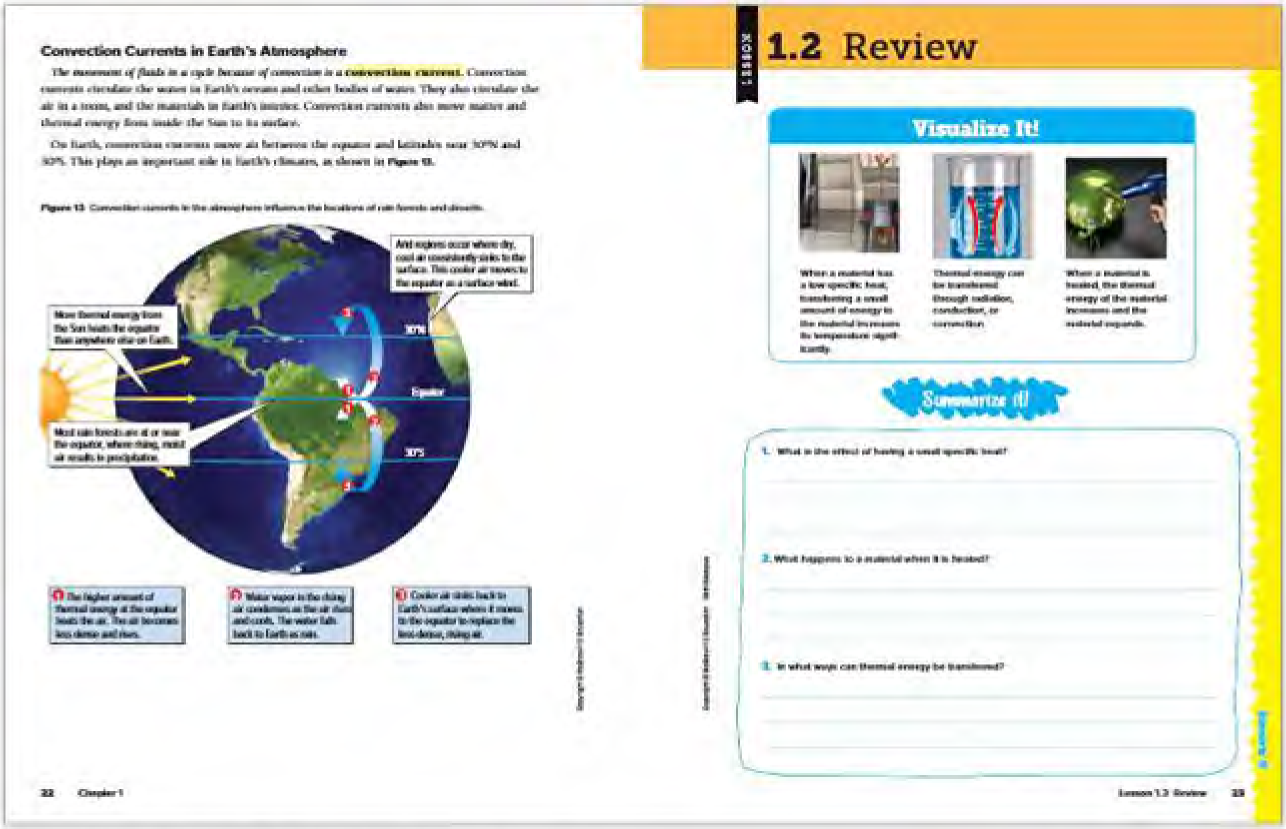
Questions and Answers Before students read the section "Convection Currents in Earth's Atmosphere," have them create a list of questions about this topic. Then as they read, or after the reading is completed, have students look for answers to their questions in the text.

Teacher Demo

Creating Convection Currents Place a beaker of water on a hot plate add a drop or two of cold food coloring. As the hot plate heats the water on the bottom of the beaker, it becomes less dense than the cooler water above, so it rises. The food coloring enables you to see the currents within the water as the thermal energy transfers throughout.

Real-World Science

Ocean Energy Ocean Thermal Energy Conversion (OTEC) is an energy technology that uses temperature differences between surface water and deep water in the ocean to generate electrical energy. OTEC is a promising alternative energy resource because OTEC power plants can produce electricity 24 hours a day, 365 days per year.



Convection Currents in Earth's Atmosphere

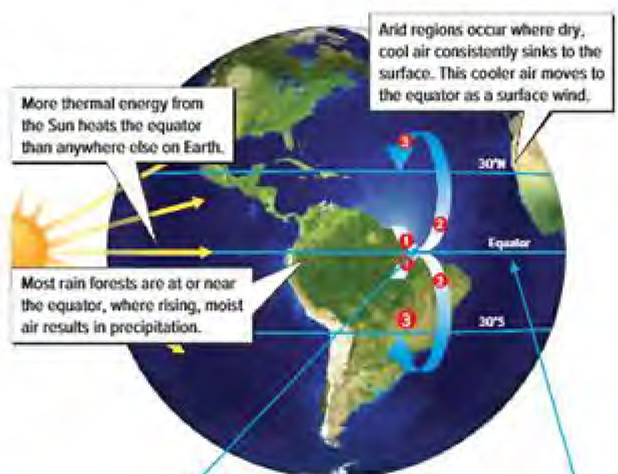
Students probably know the term *current* to mean a flow of water, as in a river or stream. They can visualize this movement to help them understand convection currents. Explain that convection currents are circular movements between hot and cold areas of gases or liquids.

Guiding Questions

OL **How do convection currents affect the temperature of the ocean?**	*Warm water is usually near the surface of the ocean, and colder water is deeper. A vertical convection requires warm water below the cold.*
BL **What does the fact that convection currents move thermal energy to the surface of the Sun tell you about the Sun?**	*Students might note that the Sun is not solid and that the surface of the Sun is not as hot as its interior.*

Visual Literacy: Convection Currents in Earth's Atmosphere

Figure 13 illustrates how the location of rain forests and deserts on Earth is because of convection currents in the atmosphere. Rain falls where air is rising, but descending air dries out the land. Use this illustration and the following questions to explain how this happens.



Ask: **What do the arrows on the diagram represent?** *The convection currents in Earth's atmosphere.*

Ask: **Where on Earth is the greatest thermal energy transferred from the Sun?** *near the equator* **Why are most rain forests between 20°N and 20°S?** *That is the area where rain falls—just to the north and south of the equator.*

Ask: What happens after the hot air near the equator rises? *It radiates thermal energy back into space, which causes it lose moisture. The cool, dry air then sinks back to Earth near 30°N and 30°S, which is where the largest deserts are on Earth.*

Visual Summary

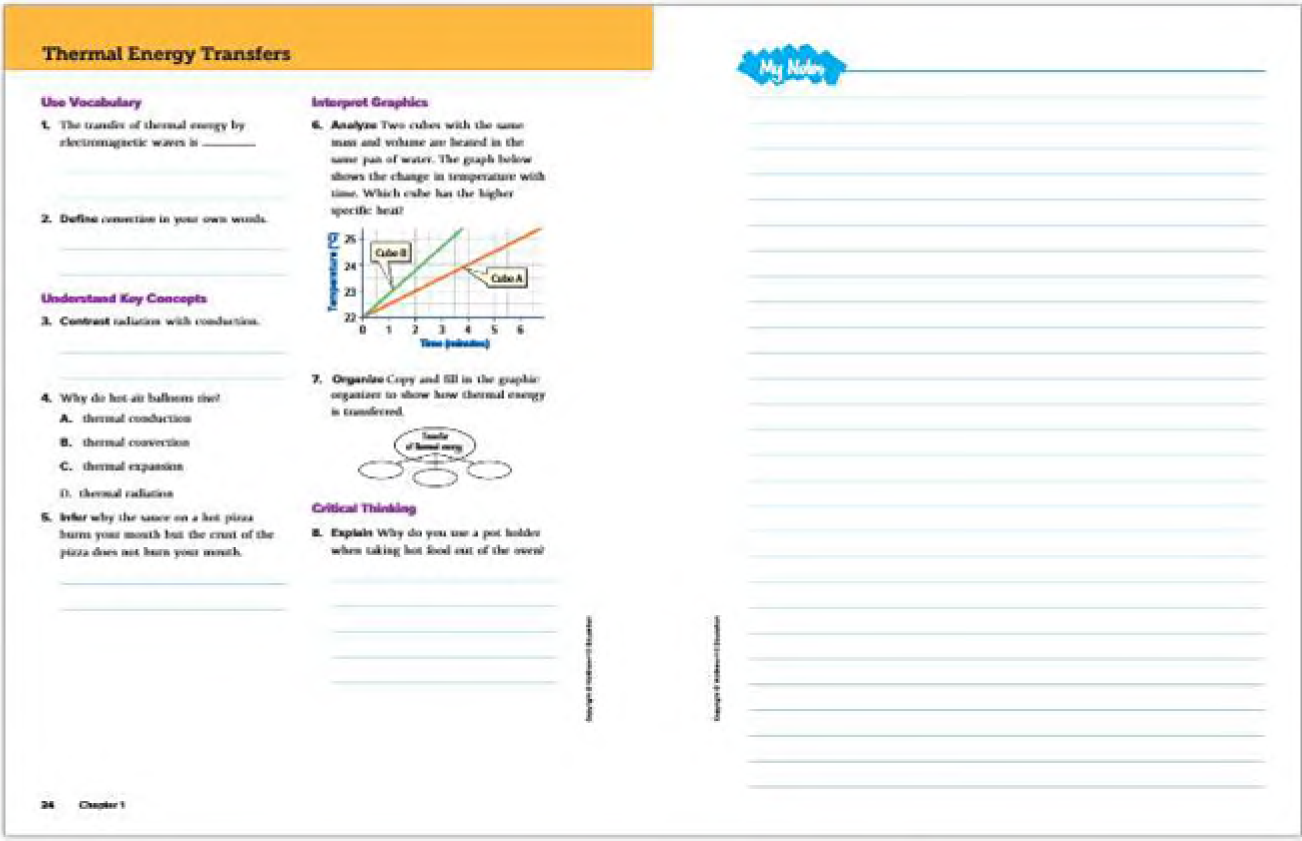
Concepts and terms are easier to remember when they are associated with an image. **Ask: To which Key Concept does each image relate?**

Summarize it!

The information needed to complete this graphic organizer can be found in the following sections:

- How is thermal energy transferred?
- Radiation
- Conduction
- Thermal Expansion and Contraction
- Convection

Teacher Notes



Thermal Energy Transfers

Use Vocabulary

1. The transfer of thermal energy by electromagnetic waves is ________

2. **Define** convection in your own words.

Understand Key Concepts

3. **Contrast** radiation with conduction.

4. Why do hot-air balloons rise?
   A. thermal conduction
   B. thermal convection
   C. thermal expansion
   D. thermal radiation

5. **Infer** why the sauce on a hot pizza burns your mouth but the crust of the pizza does not burn your mouth.

Interpret Graphics

6. **Analyze** Two cubes with the same mass and volume are heated in the same pan of water. The graph below shows the change in temperature with time. Which cube has the higher specific heat?

7. **Organize** Copy and fill in the graphic organizer to show how thermal energy is transferred.

Critical Thinking

8. **Explain** Why do you use a pot holder when taking hot food out of the oven?

24 Chapter 1

My Notes

Use Vocabulary

1. radiation

2. Convection is thermal energy transferred from one location to another in a fluid because of differences in density of warmer and cooler parts of the fluid.

Understand Key Concepts

3. Conduction is the transfer of thermal energy between materials in contact with each other. Radiation is the transfer of thermal energy from a warmer material to a cooler material without contact.

4. C. thermal expansion

5. Even though the sauce and crust have the same temperature, the pizza sauce has a high specific heat and contains more thermal energy.

Interpret Graphics

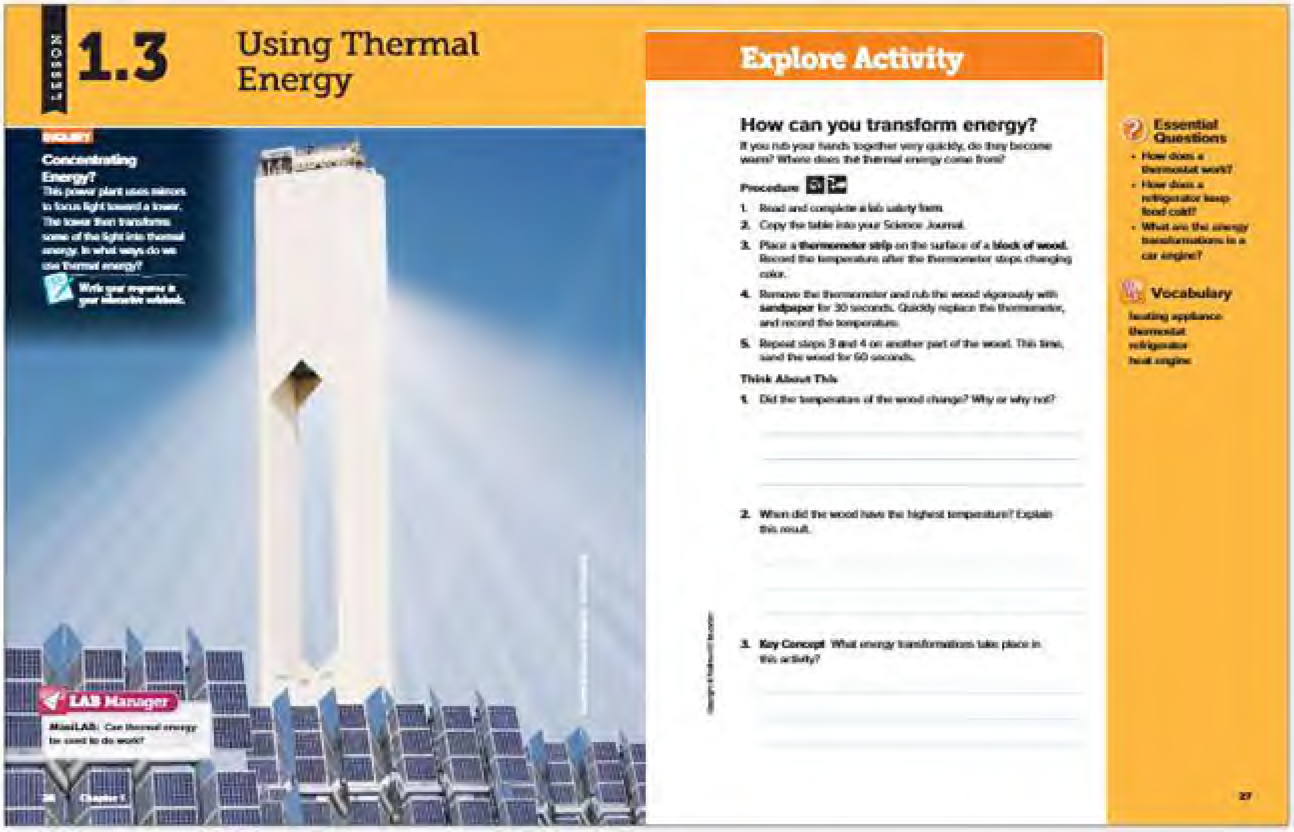
6. Cube A

7. Conduction, Convection, Radiation (in any order)

Critical Thinking

8. Pot holders are good thermal insulators. They slow the heat transfer from the hot pan to your hands.

Teacher Notes



INQUIRY

About the Photo **Concentrating Energy?** The mirrors on this power plant concentrate a large area of sunlight into a small beam, which is at a much higher temperature. The thermal energy can then be stored before it is converted to electrical energy. By concentrating the solar thermal energy in this way, the size of the power plant can be smaller.

Guiding Questions

AL **What kind of energy do you see in this photo?**	*Students may say thermal energy or solar energy.*
OL **How do power plants use solar thermal energy?**	*Solar thermal energy can be converted into electricity.*
BL **What are some advantages of using solar thermal energy?**	*Students might say that energy from the Sun is free, renewable, inexhaustible, and nonpolluting.*

LAB Manager

Labs can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Prior Knowledge

1. Write each of the four vocabulary terms on the board.
2. Divide students into groups. Ask the group to read the lesson title and the vocabulary terms and list what they are sure they know and what they think they know about each vocabulary term. For example, students may not know for sure what *heating appliance* means, but they may be able to make a guess based on the meanings of each word. They may also be able to give examples of heating appliances without knowing the actual definition of the term.
3. Have each group share what they wrote. Use the class discussion to learn what prior knowledge students may have of the four terms and to address possible misconceptions.
4. Facilitate a discussion about devices that use and control thermal energy and how our lives might be different without these devices.

Explore Activity

How can you transform energy?

Prep: *5 min* **Class:** *15 min*

Purpose
To observe how mechanical energy can be converted to thermal energy.

Materials
one-fourth of a sheet of medium grit sandpaper (or steel wool) cut into four equal pieces, 15-cm length of a 2 × 4 piece of wood, liquid-crystal, Celsius thermometer strips (available as aquarium thermometers.)

Before You Begin
Ask students how they might increase the temperature of something without using a lamp or a flame. Remind students that, when they rub their hands together, their hands get warmer. Where did the thermal energy come from?

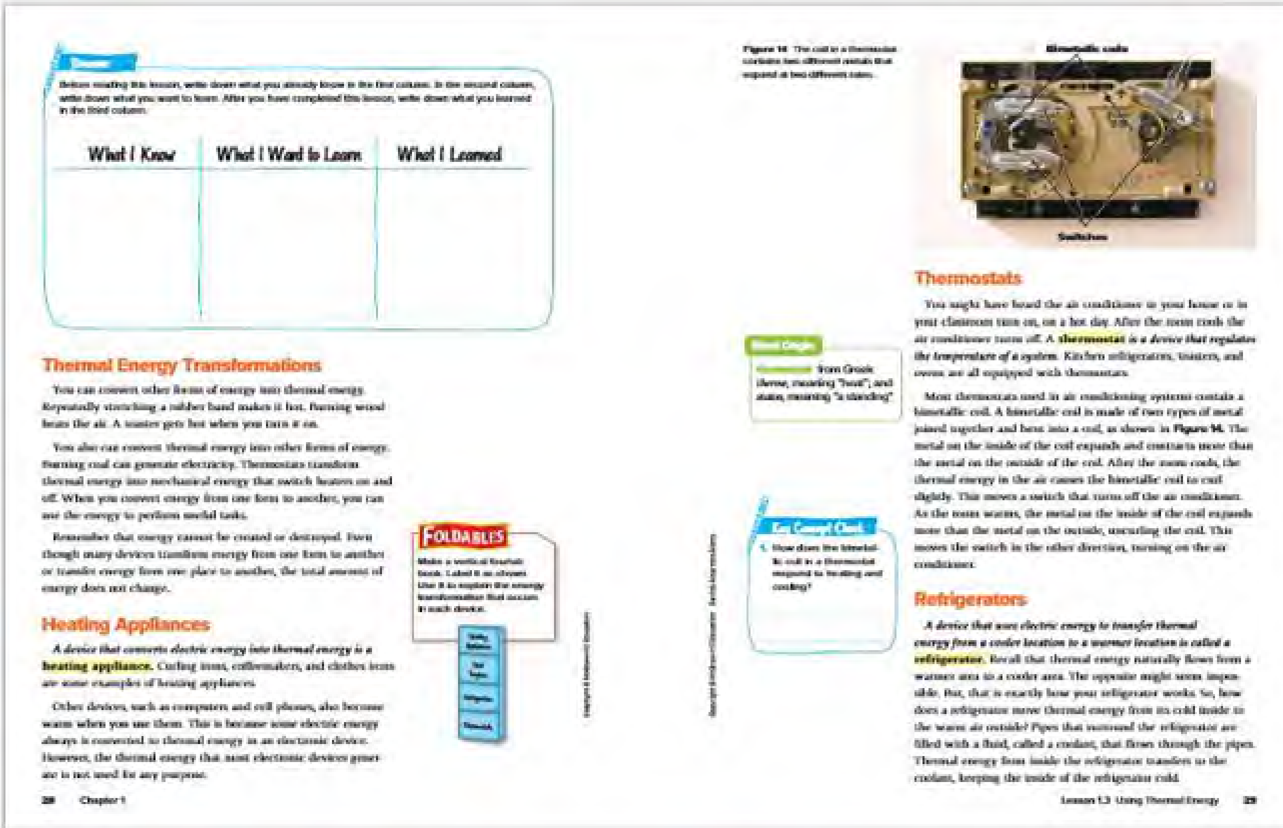
Guide the Investigation

- Demonstrate how to hold the sandpaper. Tell students to use firm pressure on the wood and move the sandpaper back and forth over the same 4–5 cm long section.
- Remind students to wait for the indicator on the strip thermometer to stop moving before recording the temperature.

Think About This

1. The temperature of the wood increased. Student answers will vary as to why. Some may know that the mechanical energy from rubbing the wood was converted into thermal energy.
2. The sample that was rubbed for 60 s had the higher temperature because more mechanical energy was converted into thermal energy for this sample.
3. **Key Concept** Mechanical energy is transformed into thermal energy in this activity. Students may also correctly say that chemical energy from their bodies is transformed into the mechanical energy for this activity.

Teacher Notes


What I Know | What I Want to Learn | What I Learned

Thermal Energy Transformations

You can convert other forms of energy into thermal energy. Repeatedly stretching a rubber band makes it hot. Burning wood heats the air. A toaster gets hot when you turn it on.

You also can convert thermal energy into other forms of energy. Burning coal can generate electricity. Thermostats transform thermal energy into mechanical energy that switch heaters on and off. When you convert energy from one form to another, you can use the energy to perform useful tasks.

Remember that energy cannot be created or destroyed. Even though many devices transform energy from one form to another or transfer energy from one place to another, the total amount of energy does not change.

Heating Appliances

A device that converts electric energy into thermal energy is a **heating appliance.** Curling irons, coffeemakers, and clothes irons are some examples of heating appliances.

Other devices, such as computers and cell phones, also become warm when you use them. This is because some electric energy always is converted to thermal energy in an electronic device. However, the thermal energy that most electronic devices generate is not used for any purpose.

FOLDABLES

Bimetallic coils

Switches

Thermostats

You might have heard the air conditioner in your house or in your classroom turn on, on a hot day. After the room cools the air conditioner turns off. A **thermostat** *is a device that regulates the temperature of a system.* Kitchen refrigerators, toasters, and ovens are all equipped with thermostats.

Most thermostats used in air conditioning systems contain a bimetallic coil. A bimetallic coil is made of two types of metal joined together and bent into a coil, as shown in **Figure 14.** The metal on the inside of the coil expands and contracts more than the metal on the outside of the coil. After the room cools, the thermal energy in the air causes the bimetallic coil to curl slightly. This moves a switch that turns off the air conditioner. As the room warms, the metal on the inside of the coil expands more than the metal on the outside, uncurling the coil. This moves the switch in the other direction, turning on the air conditioner.

Refrigerators

A device that uses electric energy to transfer thermal energy from a cooler location to a warmer location is called a **refrigerator.** Recall that thermal energy naturally flows from a warmer area to a cooler area. The opposite might seem impossible. But, that is exactly how your refrigerator works. So, how does a refrigerator move thermal energy from its cold inside to the warm air outside? Pipes that surround the refrigerator are filled with a fluid, called a coolant, that flows through the pipes. Thermal energy from inside the refrigerator transfers to the coolant, keeping the inside of the refrigerator cold.

28 Chapter 1 | Lesson 1.3 Using Thermal Energy 29

Thermal Energy Transformations

Use the guiding questions below to start a discussion that connects observations from the **Launch Lab** with the meaning of energy transformations.

Guiding Questions

AL **Why would we want to transform thermal energy into another kind of energy?**	*Students should note that energy transformations enable us to do work, such as when thermal energy is converted into mechanical energy in cars and this makes the car move.*
OL **What happens to the total amount of energy during an energy transformation?**	*One form of energy is transferred into another form of energy. The total amount of energy stays the same.*

Heating Appliances

Students should understand that heating appliances are not just devices that get hot when they are in use (like a computer), but rather devices that convert electrical energy into thermal energy to serve a useful purpose such as cooking, drying, or space heating.

Ask: What heating appliances do you have at home? *Students may say clothes irons, coffeemakers, electric ovens, electric blankets, toasters, waffle irons, and electric space heaters.*

Thermostats

Some students may confuse thermostats with thermometers. Both make use of thermal expansion. Students should understand that you can set a heating system's thermostat to a certain temperature and the temperature in the room will increase or decrease until it reaches that set temperature. Use the following questions to help students understand how thermostats work.

Guiding Questions

AL **How is a thermostat different from a thermometer?**	*A thermometer measures temperature and a thermostat regulates the temperature of a system.*
OL **How does the bimetallic coil in a thermostat respond to heating and cooling?**	*The bimetallic coil expands and uncurls when heated and contracts curling more tightly when cooled.*
BL **How can using a thermostat save energy in your home?**	*You can program a thermostat to stay at a lower temperature at night or when you are not at home, which means your heating system will use less energy during those times.*

Refrigerators

Students will be familiar with refrigerators, yet most will not know how they work. A refrigerator contains a coolant that moves thermal energy from inside of the refrigerator to outside of the refrigerator. Use these questions to help students understand that refrigerators use electrical energy to move thermal energy.

Guiding Questions

AL **What type of energy operates a refrigerator?**	*Students should note that refrigerators operate with electrical energy.*
OL **What type of energy does the coolant in a refrigerator move?**	*thermal energy*
BL **How are air conditioners similar to refrigerators?**	*Air conditioners have coolant that transfers thermal energy from the inside to the outside.*

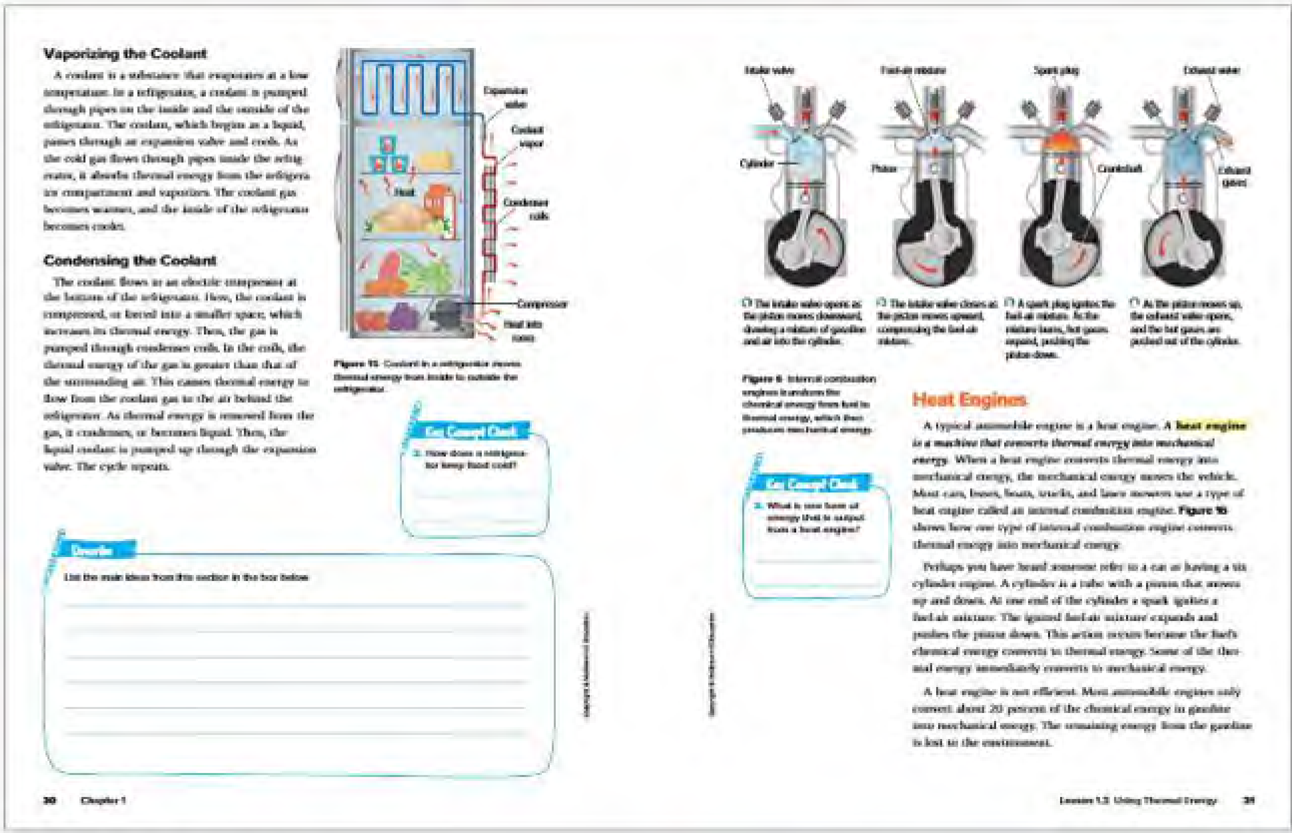
Word Origin

thermostat

Ask: **What other words do you know with the prefix *therm-*?** *thermometer, thermos, thermal*

Ask: **How does the word statos meaning "a standing" relate to the word thermostat?** *A thermostat can stay or "stand" at a set temperature.*

Teacher Notes



Vaporizing the Coolant

Condensing the Coolant

Use the following questions and **Figure 15** to help students understand how electrical energy and mechanical energy are used to transfer thermal energy and provide refrigeration.

Guiding Questions

AL **What kind of energy is used to force the liquid coolant up through a pipe to change to a gas?**	*electrical energy*
AL **What kind of energy compresses the coolant gas at the bottom of the refrigerator?**	*mechanical energy*
OL **How is thermal energy transferred to the coolant in a refrigerator?**	*Electrical energy forces liquid coolant through a valve. This turns the coolant into a gas. Thermal energy transfers from inside the refrigerator into the coolant gas. This warms the gas and cools the inside of the refrigerator.*
OL **How is thermal energy transferred out of the coolant in a refrigerator?**	*The coolant gas passes through a compressor, which increases the temperature of the gas. Thermal energy moves out of the warmer coolant gas and into the air around the refrigerator.*
BL **By what process does thermal energy transfer from inside the refrigerator to the coolant gas in the pipes?**	*conduction*
BL **How could better insulation make a refrigerator more efficient?**	*Better insulation would keep warm air from being transferred to inside the refrigerator, decreasing the amount of time that the compressor is on.*

Heat Engines

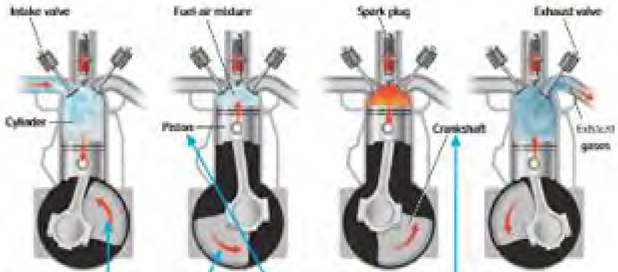
A heat engine is a machine that converts thermal energy into mechanical energy. Students may already know that an automobile engine is a heat engine, but they may need help understanding how heat engines work. Use the following questions to help students understand this concept.

Guiding Questions

AL **What does a heat engine do?**	*A heat engine converts thermal energy into mechanical energy.*
OL **What is one type of energy that is output from a heat engine?**	*Possible answers include wasted thermal energy and mechanical energy.*
BL **Explain how an internal combustion engine is an application of thermal expansion.**	*Heating the air in the cylinder causes the air to expand, which increases the volume of the air. This increased pressure pushes the piston down.*

Visual Literacy: Internal Combustion Engine

Use **Figure 16** and these questions to help students understand how an internal combustion engine uses the transfer of thermal energy.



1. The intake valve opens as the piston moves downward, drawing a mixture of gasoline and air into the cylinder.
2. The intake valve closes as the piston moves upward, compressing the fuel-air mixture.
3. A spark plug ignites the fuel-air mixture. As the mixture burns, hot gases expand, pushing the piston down.
4. As the piston moves up, the exhaust valve opens, and the hot gases are pushed out of the cylinder.

Ask: What do the arrows in the pictures represent? *They represent the movement of the pistons, gasoline, crankshaft, and gases.*

Ask: What is the relationship between the movement of the piston and the crankshaft? *When the piston moves up and down, the crankshaft rotates clockwise.*

Differentiated Instruction

AL **A Step-by-Step Guide** Have students reread the section titled **Refrigerators** and create a step-by-step guide explaining how they work in their own words. Students can write the directions as though they were trying to teach someone else how to make a refrigerator work.

BL **Venn Diagram** Have students create a Venn diagram that compares heating appliances to refrigerators in terms of how they work. Students should use the terms thermal energy and transfer in their descriptions.

Teacher Toolbox

Fun Fact

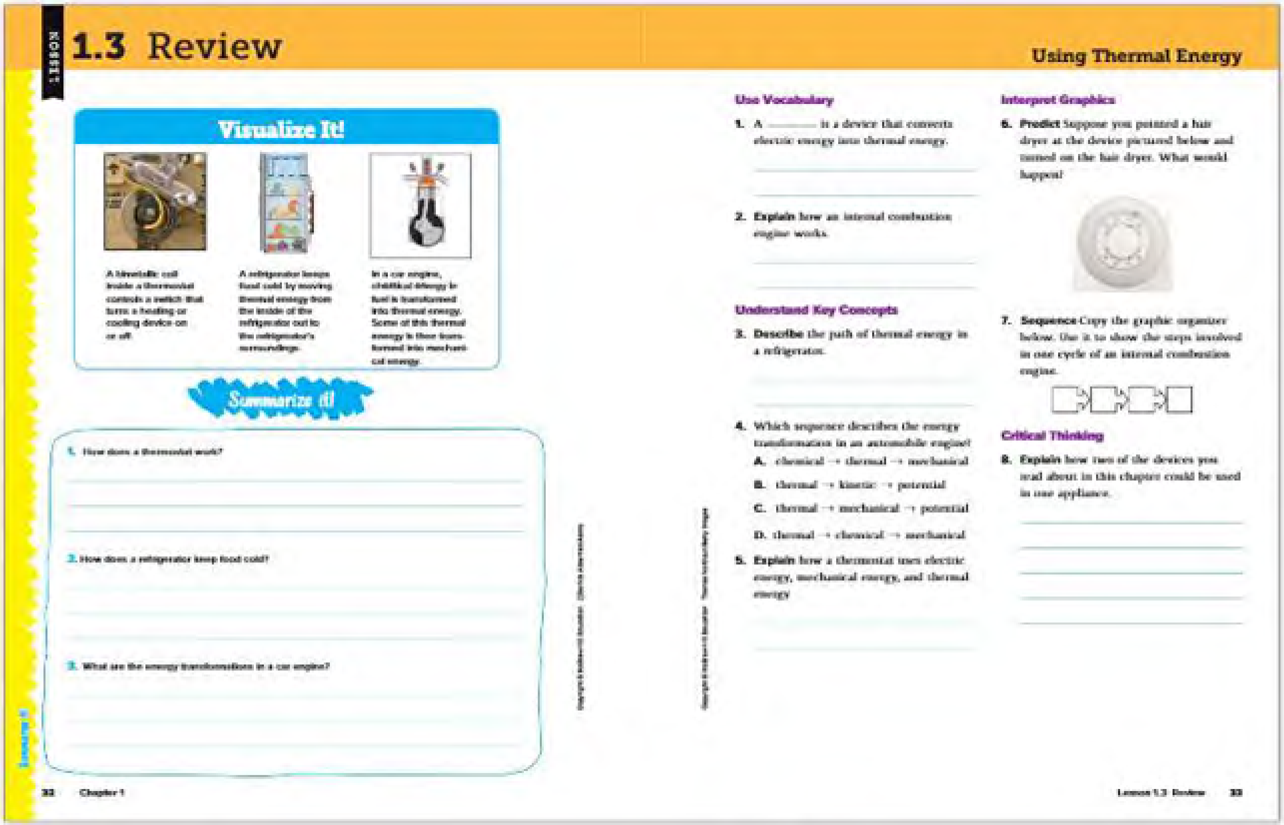
The First Refrigerator In 1803, Maryland farmer Thomas Moore invented the first "refrigerator." He built it in order to keep butter cool as he transported it from his farm to the market center in Washington, D.C. Moore invented a kind of "ice box" out of a cedar tub that was insulated with rabbit fur, filled with ice, and wrapped in a piece of sheet metal.

Reading Strategy

Paraphrase Have students paraphrase what they have read in this section, including the concepts that are important to the section. Students can compare their paraphrases to see if they put the concepts into their own words without leaving out essential information.

Cultural Diversity

The Zeer Pot In 2006, a Nigerian teacher, Mohammed Bah Abba, invented the zeer pot to keep food fresh in places that did not have refrigeration. The zeer is a large pot with a clay lid with a smaller pot inside it. The space between the two pots is filled with sand, which insulates the inner pot. The sand is kept damp by adding water twice a day. As the water from the sand evaporates, it draws heat from the inner pot, leaving it cooler.



LESSON 1.3 Review

Visualize It!

A bimetallic coil inside a thermostat controls a switch that turns a heating or cooling device on or off.

A refrigerator keeps food cold by moving thermal energy from the inside of the refrigerator out to the refrigerator's surroundings.

In a car engine, chemical energy in fuel is transformed into thermal energy. Some of this thermal energy is then transformed into mechanical energy.

Summarize it!

1. How does a thermostat work?

2. How does a refrigerator keep food cold?

3. What are the energy transformations in a car engine?

32 Chapter 1

Using Thermal Energy

Use Vocabulary

1. A ______ is a device that converts electric energy into thermal energy.

2. **Explain** how an internal combustion engine works.

Understand Key Concepts

3. **Describe** the path of thermal energy in a refrigerator.

4. Which sequence describes the energy transformation in an automobile engine?
   A. chemical → thermal → mechanical
   B. thermal → kinetic → potential
   C. thermal → mechanical → potential
   D. thermal → chemical → mechanical

5. **Explain** how a thermostat uses electric energy, mechanical energy, and thermal energy.

Interpret Graphics

6. **Predict** Suppose you pointed a hair dryer at the device pictured below and turned on the hair dryer. What would happen?

7. **Sequence** Copy the graphic organizer below. Use it to show the steps involved in one cycle of an internal combustion engine.

Critical Thinking

8. **Explain** how two of the devices you read about in this chapter could be used in one appliance.

Lesson 1.3 Review 33

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Ask: Which Key Concept does each image relate to?**

Summarize it!

The information needed to complete this graphic organizer can be found in the following sections:

- Thermal Energy Transformations
- Heating Appliances
- Thermostats
- Refrigerators
- Heat Engines

Use Vocabulary

1. heating appliance

2. An internal combustion engine converts the chemical energy in fuel into thermal energy and then mechanical energy.

Understand Key Concepts

3. Thermal energy moves from the refrigerator compartment into the coolant. The coolant is then pumped to the compressor. Finally, the thermal energy moves from the coolant into the surrounding environment.

4. A. chemical • thermal • mechanical

5. Thermal energy causes the bimetallic coil to curl or uncurl. Mechanical energy from the moving bimetallic coil turns an electric switch on or off. Electrical energy turns the furnace on or off.

Interpret Graphics

6 The coil would unwind, tilt the switch, and turn the heater off.

7. The downward moving piston draws in fuel mixture. → The upward moving piston compresses the fuel mixture. → Thermal expansion of the ignited fuel mixture forces the piston downward. → The upward moving piston forces the exhaust out of the cylinder.

Critical Thinking

8. Possible answer: coupling a thermostat with an iron or a refrigerator to control the temperature of the appliance

Teacher Toolbox

Fun Fact

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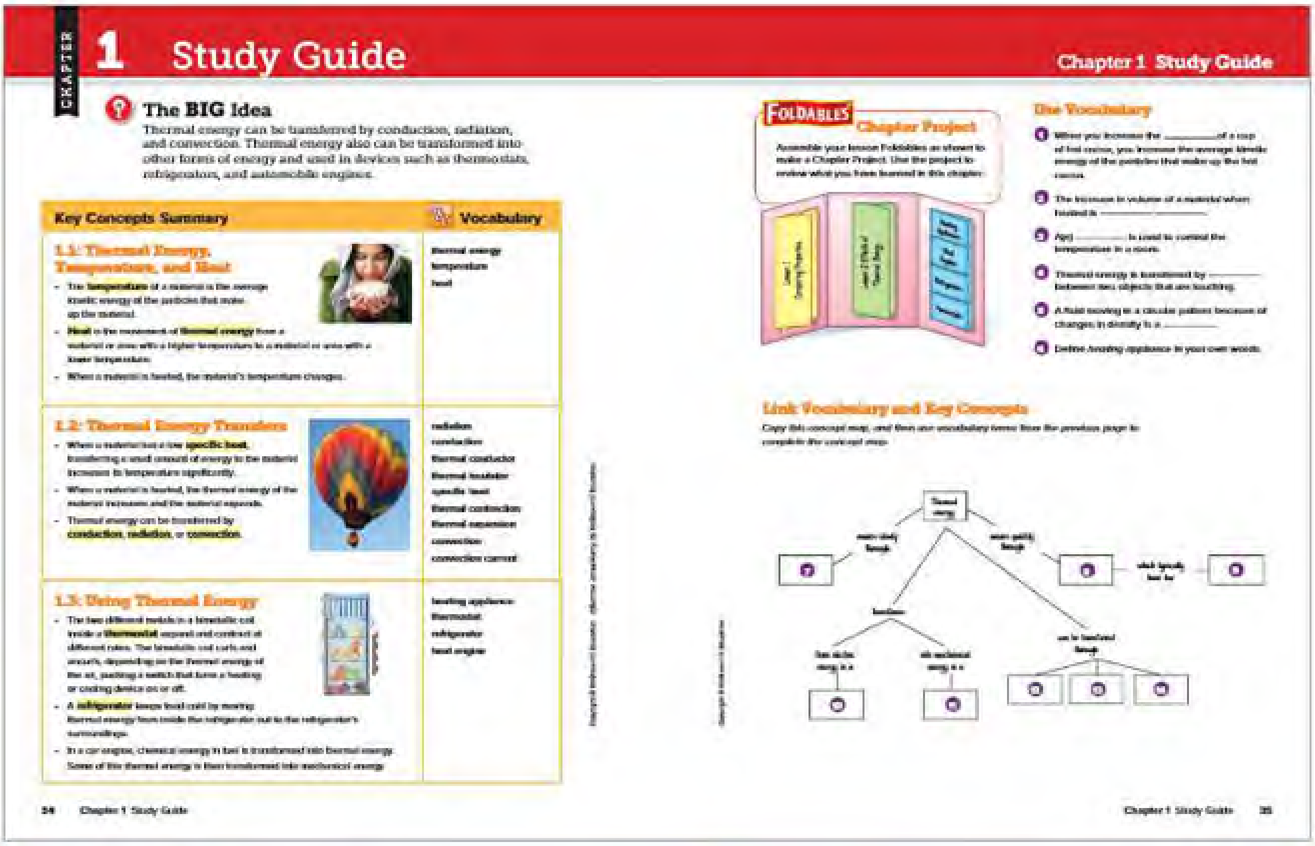
Reading Strategy

Paraphrase Have students paraphrase what they have read in this section, including the concepts that are important to the section. Students can compare their paraphrases to see if they put the concepts into their own words without leaving out essential information.

Cultural Diversity

The Zeer Pot In 2006, a Nigerian teacher, Mohammed Bah Abba, invented the zeer pot to keep food fresh in places that did not have refrigeration. The zeer is a large pot with a clay lid with a smaller pot inside it. The space between the two pots is filled with sand, which insulates the inner pot. The sand is kept damp by adding water twice a day. As the water from the sand evaporates, it draws heat from the inner pot, leaving it cooler.



CHAPTER 1 Study Guide

The BIG Idea

Thermal energy can be transferred by conduction, radiation, and convection. Thermal energy also can be transformed into other forms of energy and used in devices such as thermostats, refrigerators, and automobile engines.

Key Concepts Summary	Vocabulary
1.1: Thermal Energy, Temperature, and Heat	thermal energy temperature heat
1.2: Thermal Energy Transfers	radiation conduction thermal conductor thermal insulator specific heat thermal contraction thermal expansion convection convection current
1.3: Using Thermal Energy	heating appliance thermostat refrigerator heat engine

34 Chapter 1 Study Guide

Chapter 1 Study Guide

FOLDABLES Chapter Project

Use Vocabulary

Link Vocabulary and Key Concepts

Chapter 1 Study Guide 35

Key Concepts Summary

Study Strategy: Synthesis

One way to help students know if they understand Key Concepts is to have students write Key Concepts in their own words. Students should think about how they would explain these concepts to someone who has not read the text.

1. Ask students to draw a chart like the one below in their Science Journals, listing each Key Concept in the left column.
2. Prompt students to read the Key Concepts Summary.
3. For each Key Concept, have them first put in their own words. Then have them explain why the particular statement was chosen as a Key Concept.
4. Once students have completed the chart, they can share their ideas with other students to discuss how each Key Concept relates to other concepts.

Example:

Key Concept	In my own words	Why this statement is a key concept

Vocabulary

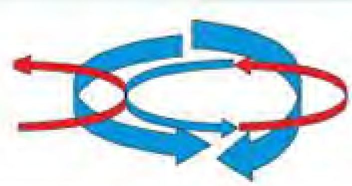
Study Strategy: Visual Representation

Some of this chapter's vocabulary terms are similar and students may confuse them, such as conduction and convection. Such terms can be understood and remembered more easily if students create their own visual representations for the words.

1. Have students select the 5–8 vocabulary words that they have the most difficulty remembering or understanding.
2. Provide students with index cards. Instruct them to draw one illustration per card to represent each of the chosen words. Then allow them to cut photos from magazines to illustrate the terms. They may create more than one visual for each word.
3. Students can then share their illustration and photo cards with each other and try to guess which vocabulary term they represent.

Example:

This illustration represents a convection current.



FOLDABLES® Chapter Project

Use the Foldables® Chapter Project as a way to connect Key Concepts.

1. Ask students to organize their Foldables® in a way that reflects how the concepts in each Foldable relate to each other.
2. Use glue or staples to hold the sheets together as needed.
3. When complete, ask students to place their Foldables® Chapter Project at the front of the room. Have the class critique and discuss the way in which students have organized their Foldables®.

Use Vocabulary

1. temperature
2. thermal expansion
3. thermostat
4. conduction
5. convection current
6. Sample answer: A heating appliance is a device that converts electric energy into thermal energy.

Link Vocabulary and Key Concepts

7 thermal insulators

8 thermal conductors

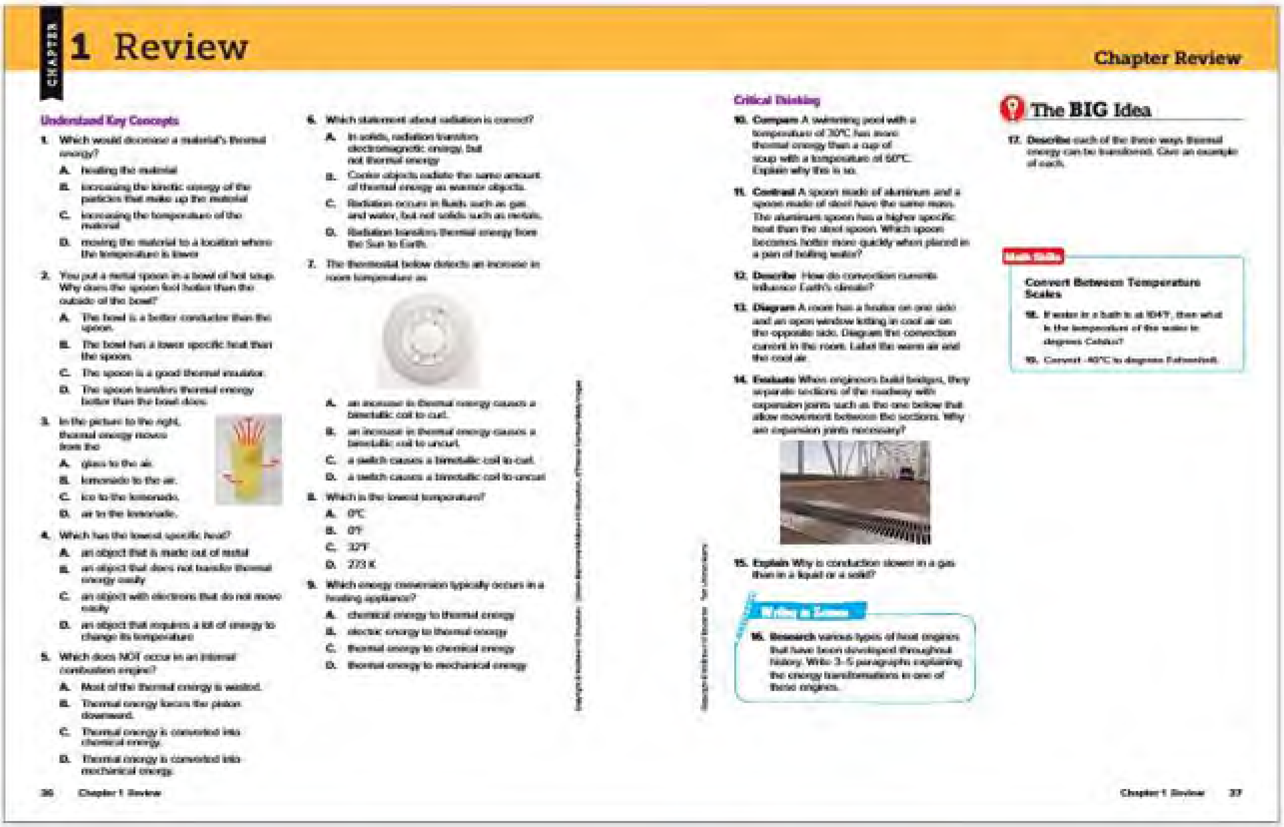
9 specific heat

10 heating appliance

11 heat engine

12 13 14 conduction/convection/radiation

Teacher Notes



CHAPTER 1 Review

Chapter Review

Understand Key Concepts

1. Which would decrease a material's thermal energy?
   A. heating the material
   B. increasing the kinetic energy of the particles that make up the material
   C. increasing the temperature of the material
   D. moving the material to a location where the temperature is lower

2. You put a metal spoon in a bowl of hot soup. Why does the spoon feel hotter than the outside of the bowl?
   A. The bowl is a better conductor than the spoon.
   B. The bowl has a lower specific heat than the spoon.
   C. The spoon is a good thermal insulator.
   D. The spoon transfers thermal energy better than the bowl does.

3. In the picture to the right, thermal energy moves from the
   A. glass to the air.
   B. lemonade to the air.
   C. ice to the lemonade.
   D. air to the lemonade.

4. Which has the lowest specific heat?
   A. an object that is made out of metal
   B. an object that does not transfer thermal energy easily
   C. an object with electrons that do not move easily
   D. an object that requires a lot of energy to change its temperature

5. Which does NOT occur in an internal combustion engine?
   A. Most of the thermal energy is wasted.
   B. Thermal energy forces the piston downward.
   C. Thermal energy is converted into chemical energy.
   D. Thermal energy is converted into mechanical energy.

6. Which statement about radiation is correct?
   A. In solids, radiation transfers electromagnetic energy, but not thermal energy.
   B. Cooler objects radiate the same amount of thermal energy as warmer objects.
   C. Radiation occurs in fluids such as gas and water, but not solids such as metals.
   D. Radiation transfers thermal energy from the Sun to Earth.

7. The thermostat below detects an increase in room temperature as
   A. an increase in thermal energy causes a bimetallic coil to curl.
   B. an increase in thermal energy causes a bimetallic coil to uncurl.
   C. a switch causes a bimetallic coil to curl.
   D. a switch causes a bimetallic coil to uncurl.

8. Which is the lowest temperature?
   A. 0°C
   B. 0°F
   C. 32°F
   D. 273 K

9. Which energy conversion typically occurs in a heating appliance?
   A. chemical energy to thermal energy
   B. electric energy to thermal energy
   C. thermal energy to chemical energy
   D. thermal energy to mechanical energy

Critical Thinking

10. **Compare** A swimming pool with a temperature of 30°C has more thermal energy than a cup of soup with a temperature of 60°C. Explain why this is so.

11. **Contrast** A spoon made of aluminum and a spoon made of steel have the same mass. The aluminum spoon has a higher specific heat than the steel spoon. Which spoon becomes hotter more quickly when placed in a pan of boiling water?

12. **Describe** How do convection currents influence Earth's climate?

13. **Diagram** A room has a heater on one side and an open window letting in cool air on the opposite side. Diagram the convection current in the room. Label the warm air and the cool air.

14. **Evaluate** When engineers build bridges, they separate sections of the roadway with expansion joints such as the one below that allow movement between the sections. Why are expansion joints necessary?

15. **Explain** Why is conduction slower in a gas than in a liquid or a solid?

Writing in Science

16. **Research** various types of heat engines that have been developed throughout history. Write 3–5 paragraphs explaining the energy transformations in one of these engines.

The BIG Idea

17. **Describe** each of the three ways thermal energy can be transferred. Give an example of each.

Math Skills

Convert Between Temperature Scales

18. If water in a bath is at 104°F, then what is the temperature of the water in degrees Celsius?

19. Convert -40°C to degrees Fahrenheit.

36 Chapter 1 Review

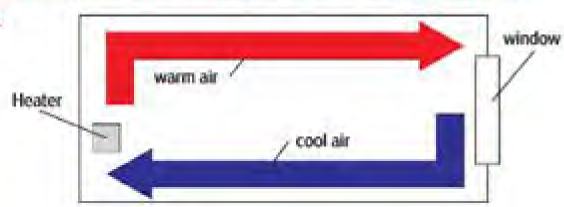
Chapter 1 Review 37

Understand Key Concepts

1. D. moving the material to a location where the temperature is lower
2. D. The spoon transfers thermal energy better than the bowl does.
3. A. air to the lemonade.
4. A. an object that is made out of metal
5. C. Thermal energy is converted into chemical energy.
6. D. Radiation transfers thermal energy from the Sun to Earth.
7. B. an increase in thermal energy causes a bimetallic coil to uncurl.
8. B. 0°F
9. B. electric energy to thermal energy

Critical Thinking

10. The swimming pool has more thermal energy because many more particles make up the water in a swimming pool than make up the soup in a cup of soup.
11. The steel spoon because it takes less thermal energy to change the temperature of a material with a lower specific heat.
12. Convection currents move between warm regions, such as at the Equator, and cooler locations. Radiation at warm areas warms the air, which becomes less dense. Denser, cooler air moves in to replace the warm air, forcing it upward. The rising air cools and loses moisture, providing the conditions for rain forests to grow near the Equator. It then moves aloft until it descending back toward Earth. The descending air is cool and dry, which provides the conditions for deserts at 30°.
13.



14. Without expansion joints, a bridge might buckle or separate as a result of thermal expansion in the summer and thermal contraction in the winter.

15. Conduction is slower in a gas than in a liquid or solid because particles in a gas are farther apart then particle are in a liquid or solid.

Writing in Science

16. Possible answers: Early engines transformed the thermal energy in steam into mechanical energy. In the late 1700s, steam engines were used to move steamboats and locomotives. In the 17th century, Sir Samuel Moreland designed the first internal combustion engine, which transformed the chemical energy in gunpowder into mechanical energy. In 1879, Karl Benz was granted a patent for the two-stroke internal combustion engine. Benz also developed the four-stroke combustion engine that continues to be used in cars today.

The BIG Idea

17. Possible answers: Thermal energy can be transferred through conduction, convection, and radiation. An example of conduction is when someone touches a hot pan. An example of convection is air circulating in a room. An example of radiation is a lizard warming itself in a hot desert sun.

18. Different colors represent different amounts of thermal energy in the cars. White shows the part of the car with the greatest thermal energy. Red has the next greatest thermal energy. The dark blue is the part of the car with the least amount of thermal energy.

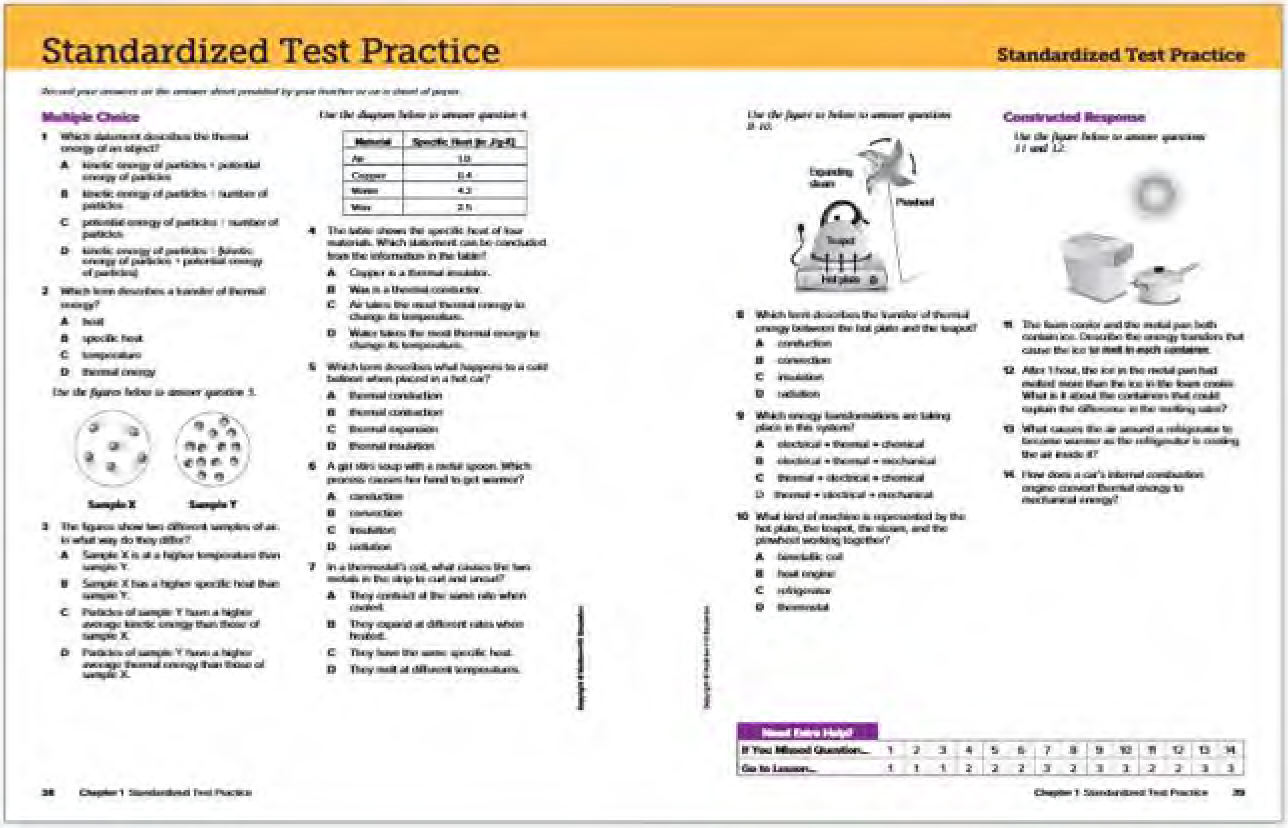
Math Skills

Solve Problems

19. 40°C

20. –40°F

Teacher Notes



Standardized Test Practice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

Multiple Choice

1 Which statement describes the thermal energy of an object?
- A kinetic energy of particles + potential energy of particles
- B kinetic energy of particles ÷ number of particles
- C potential energy of particles ÷ number of particles
- D kinetic energy of particles ÷ (kinetic energy of particles + potential energy of particles)

2 Which term describes a transfer of thermal energy?
- A heat
- B specific heat
- C temperature
- D thermal energy

Use the figures below to answer question 3.

Sample X Sample Y

3 The figures show two different samples of air. In what way do they differ?
- A Sample X is at a higher temperature than sample Y.
- B Sample X has a higher specific heat than sample Y.
- C Particles of sample Y have a higher average kinetic energy than those of sample X.
- D Particles of sample Y have a higher average thermal energy than those of sample X.

Use the diagram below to answer question 4.

Material	Specific Heat (in J/g·K)
Air	1.0
Copper	0.4
Water	4.2
Wax	2.5

4 The table shows the specific heat of four materials. Which statement can be concluded from the information in the table?
- A Copper is a thermal insulator.
- B Wax is a thermal conductor.
- C Air takes the most thermal energy to change its temperature.
- D Water takes the most thermal energy to change its temperature.

5 Which term describes what happens to a cold balloon when placed in a hot car?
- A thermal conduction
- B thermal contraction
- C thermal expansion
- D thermal insulation

6 A girl stirs soup with a metal spoon. Which process causes her hand to get warmer?
- A conduction
- B convection
- C insulation
- D radiation

7 In a thermostat's coil, what causes the two metals in the strip to curl and uncurl?
- A They contract at the same rate when cooled.
- B They expand at different rates when heated.
- C They have the same specific heat.
- D They melt at different temperatures.

Use the figure below to answer questions 8–10.

8 Which term describes the transfer of thermal energy between the hot plate and the teapot?
- A conduction
- B convection
- C insulation
- D radiation

9 Which energy transformations are taking place in this system?
- A electrical → thermal → chemical
- B electrical → thermal → mechanical
- C thermal → electrical → chemical
- D thermal → electrical → mechanical

10 What kind of machine is represented by the hot plate, the teapot, the steam, and the pinwheel working together?
- A bimetallic coil
- B heat engine
- C refrigerator
- D thermostat

Constructed Response

Use the figure below to answer questions 11 and 12.

11 The foam cooler and the metal pan both contain ice. Describe the energy transfers that cause the ice to melt in each container.

12 After 1 hour, the ice in the metal pan had melted more than the ice in the foam cooler. What is it about the containers that could explain the difference in the melting rates?

13 What causes the air around a refrigerator to become warmer as the refrigerator is cooling the air inside it?

14 How does a car's internal combustion engine convert thermal energy to mechanical energy?

Need Extra Help?

If You Missed Question...	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Go to Lesson...	1	1	1	2	2	2	3	2	3	3	2	2	3	3

38 Chapter 1 Standardized Test Practice

Chapter 1 Standardized Test Practice 39

Multiple Choice

1 **A—Correct.** B—describes average kinetic energy of particles. C describes average potential energy of the particles. D describes the fraction of kinetic energy out of thermal energy.

2 **A—Correct.** B—describes how much thermal energy it takes to raise a material to a higher temperature. C describes average kinetic energy of the particles. D describes the total potential and kinetic energy of particles that make up a material.

3 **A—Correct.** B—is incorrect because they both are the same material and thus have the same specific heat. C and D are incorrect because the opposite statements are true.

4 **D—Correct.** A, B, and C—are incorrect because the opposite statements are true.

5 **C—Correct.** A—describes a material that conducts thermal energy well. B describes the opposite of what would happen. D describes a material that conducts thermal energy poorly.

6 **A—Correct.** B—describes thermal energy transfer by currents within a fluid. C describes the situation of something preventing the transfer of heat. D describes thermal energy transfer when objects are not touching.

7 **B—Correct.** A—is incorrect because the coil would not curl if the metals contracted at the same rate. C is incorrect because if the coils had the same specific heat, then the metals would expand at the same rate and the coil would not curl. D is incorrect because melting point does not directly determine rate of expansion.

8 **A—Correct.** B—describes thermal energy transfer by currents within a fluid. C describes the case if the hot plate did not transfer thermal energy to the teapot. D describes thermal energy transfer when objects are not touching.

9 **B—Correct.** A—is incorrect because the pinwheel is not changing chemically. C and D are incorrect because the hot plate involves electrical energy transforming to thermal energy.

10 **B—Correct.** A—describes a material made of two metals that is used in thermostats. C describes an appliance that cools things. D describes a device that regulates temperature.

Constructed Response

11 Transfer of thermal energy from the Sun by radiation warms the containers. Transfer of thermal energy from the containers by conduction melts the ice.

12 The composition of the containers makes the difference. Foam is a thermal insulator, while metals are thermal conductors. The foam cooler did not transfer as much energy to the ice by conduction as the metal pot did.

13 The refrigerator coolant takes thermal energy from the air inside the refrigerator and travels to the outside coils. The coolant transfers the thermal energy to the outside coils, which transfer thermal energy to the outside air, and the air is heated.

14 When gasoline burns in the engine, it produces hot gases that expand and move the pistons. In this way, thermal energy is converted to mechanical energy (movement).

Answer Key

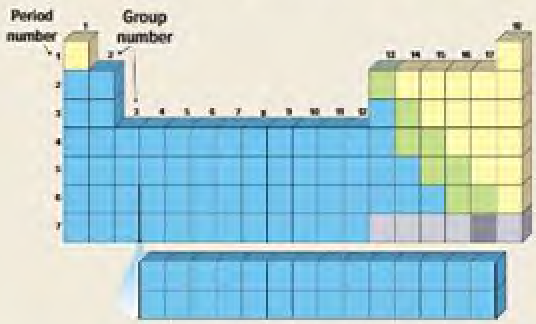
Question	Answer
1	A
2	A
3	A
4	D
5	C
6	A
7	B
8	A
9	B
10	B
11	See extended answer.
12	See extended answer.
13	See extended answer.
14	See extended answer.

Science Content Background

Lesson 1

Electrons and Energy Levels

The Periodic Table The periodic table arranges elements by periods and groups according to their physical and chemical properties. This helps scientists understand differences among elements and predict how they will react in chemical reactions.



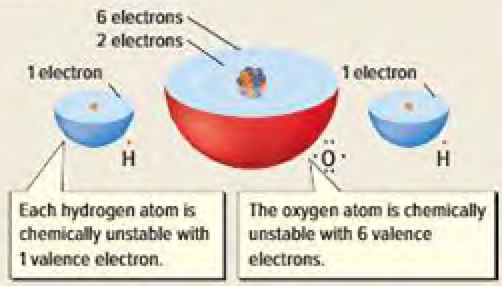
Atoms Bond When atoms of different elements combine, they form compounds. A chemical bond is a force that holds two or more atoms together. Atoms gain, lose, or share valence electrons when they form chemical bonds.

Lesson 2

Compounds, Chemical Formulas, and Covalent Bonds

From Elements to Compounds A compound is a substance made of two or more elements. Most of the materials around us are substances formed from combined elements. Compounds have different physical and chemical properties from the elements they are made from.

Covalent Bonds—Electron Sharing When two nonmetal atoms share valence electrons they form a covalent bond. Sharing valence electrons makes the atoms chemically stable and allows them to have the same electron arrangement as a noble gas. In a single covalent bond, atoms share one pair of valence electrons. In a double covalent bond, atoms share two pairs of valence electrons. In a triple covalent bond, three pairs of valence electrons are shared.



Covalent Compounds When two or more atoms share valence electrons, they form a covalent compound. Water, sugar, and carbon dioxide are examples of covalent compounds. Covalent compounds usually have low melting and boiling points. They are also usually gases or liquids at room temperature and tend to be poor conductors of thermal and electrical energy. A molecule is the smallest unit of a covalent compound. Some molecules are polar because the atoms do not share valence electrons equally. As a result, one end has a partially positive charge and one end has a partially negative charge. Other molecules are nonpolar and the atoms share valence electrons equally.

Science Content Background

Lesson 3

Ionic and Metallic Bonds

Understanding Ions An ion is an atom that is not electrically neutral because it has gained or lost one or more valence electrons. Electrons carry a negative charge. As a result, atoms that gain electrons become negatively charged ions. Atoms that lose electrons become positively charged ions.

Ionic Bonds—Electron Transferring An ionic bond is the attraction between positively and negatively charged ions. It forms when a nonmetal combines with a metal. Gaining or losing valence electrons makes the atoms chemically stable and allows them to have the same electron arrangement as a noble gas.

Ionic Compounds When ions combine, they form ionic compounds. Table salt is an example of an ionic compound. Ionic compounds are usually solid and brittle at room temperature. They also tend to have relatively high melting and boiling points. Ionic compounds do not consist of molecules. Instead, they are a collection of oppositely charged ions.

Metallic Bonds—Electron Pooling When metal atoms combine, they form a metallic bond. In a metallic bond, many metal atoms pool their valence electrons. The atoms become positively charged ions surrounded by a "sea of electrons." The valence electrons move freely from ion to ion. Metallic compounds are good conductors of thermal and electrical energy. They are also malleable, ductile, and shiny because of their metallic bonds.

Strand Map

Required Background Knowledge

To understand the Key Concepts of this chapter, students should have the following background knowledge:

* Atoms may stick together in well-defined molecules, or may be packed together in large arrays. Different arrangements of atoms compose all substances.

* The idea of atoms explains chemical reactions: When substances interact to form new substances, the atoms that make up the molecules of the original substances combine in new ways.

* There are groups of elements that have similar properties, including highly reactive metals, less-reactive metals, highly reactive nonmetals, and some almost completely non-reactive gases.

* A substance has characteristic properties, such as density, boiling point, and solubility, which are independent of the amount of the substance and can be used to identify it.

* All matter is made up of atoms, which are far too small to see directly through a microscope.

* American Association for the Advancement of Science. (1993). Benchmarks for Science Literacy. New York: Oxford University Press.

Lesson 1
Electrons and Energy Levels

1 Electrons with more energy are farther from the atom's nucleus and are in a higher energy level.

2 Atoms with fewer than eight valence electrons gain, lose, or share valence electrons and form stable compounds. Atoms in stable compounds have the same electron arrangement as a noble gas.

Lesson 2
Compounds, Chemical Formulas, and Covalent Bonds

3 A compound and the elements it is made from have different chemical and physical properties.

4 A covalent bond forms when two nonmetal atoms share valence electrons. Common properties of covalent compounds include low melting points and low boiling points. They are usually gas or liquid at room temperature and poor conductors of electricity.

5 Water is a polar compound because the oxygen atom pulls more strongly on the shared valence electrons than the hydrogen atoms.

Lesson 3
Ionic and Metallic Bonds

6a Ionic bonds form when valence electrons move from a metal atom to a nonmetal atom.

6b An ionic compound is held together by ionic bonds, which are attractions between positively and negatively charge ions.

7 A metallic bond forms when valence electrons are pooled among many metal atoms.

Identifying Misconceptions

Valence Electrons

Find Out What Students Think

Students may think that...

... all of the electrons inside an atom are free to participate in chemical bonding. They may not understand that an atom has different energy levels and that valence electrons are in the outermost layer. As a result, they are the only electrons that are free to interact with other atoms.

Discussion

Remind students that atoms have different energy levels and electrons are located in each level. Some are close to the nucleus while others are farther away. Remind students that protons in a nucleus carry a positive charge and electrons outside the nucleus carry a negative charge. Objects that are positively charged attract objects that are negatively charged. The closer the objects are, the stronger the attraction. **Ask:** Do the electrons that are close to the nucleus have a strong attraction to it or a weak attraction? **They have a strong attraction.** **Ask:** Do the electrons that are far from the nucleus have a strong attraction or a weak attraction to it? **They have a weak attraction.** **Ask:** Do you think it would it be easier for electrons to interact with other atoms if they have a strong attraction to the nucleus or a weak one? Explain your answer. **It would be easier for electrons with a weak attraction to the nucleus to interact with other atoms, because the nucleus doesn't pull on them as strongly as it does the other electrons.** **Ask:** Which electrons are free to participate in chemical bonding? **the electrons that are farthest away from the nucleus**

Promote Understanding

Activity Have students work in groups of three or four to create a table about chemical bonding.

1. Provide each group with a piece of posterboard.
2. Ask each group to draw a blank table on the posterboard. The table should have four columns labeled "Element 1," "Element 2," "Type of Bond," and "Valence Electrons."
3. In each row of the table, have students list several different pairs of elements in the "Element 1" and "Element 2" columns. Students should refer to the periodic table, and the type of element in each pair should vary (metal and metal; metal and nonmetal; nonmetal and nonmetal).
4. Next, each group should fill in the remaining cells in the table. For each pair of elements, students should write either covalent or ionic under the "Type of Bond" column. Under the "Valence Electrons" column, students should indicate that the elements share valence electrons (if the bond is covalent) or that they either gain or lose valence electrons (if the bond is ionic). For ionic bonds, students should indicate which element gains and which element loses valence electrons.

Covalent Bonds v. Ionic Bonds

Find Out What Students Think

Students may think that...

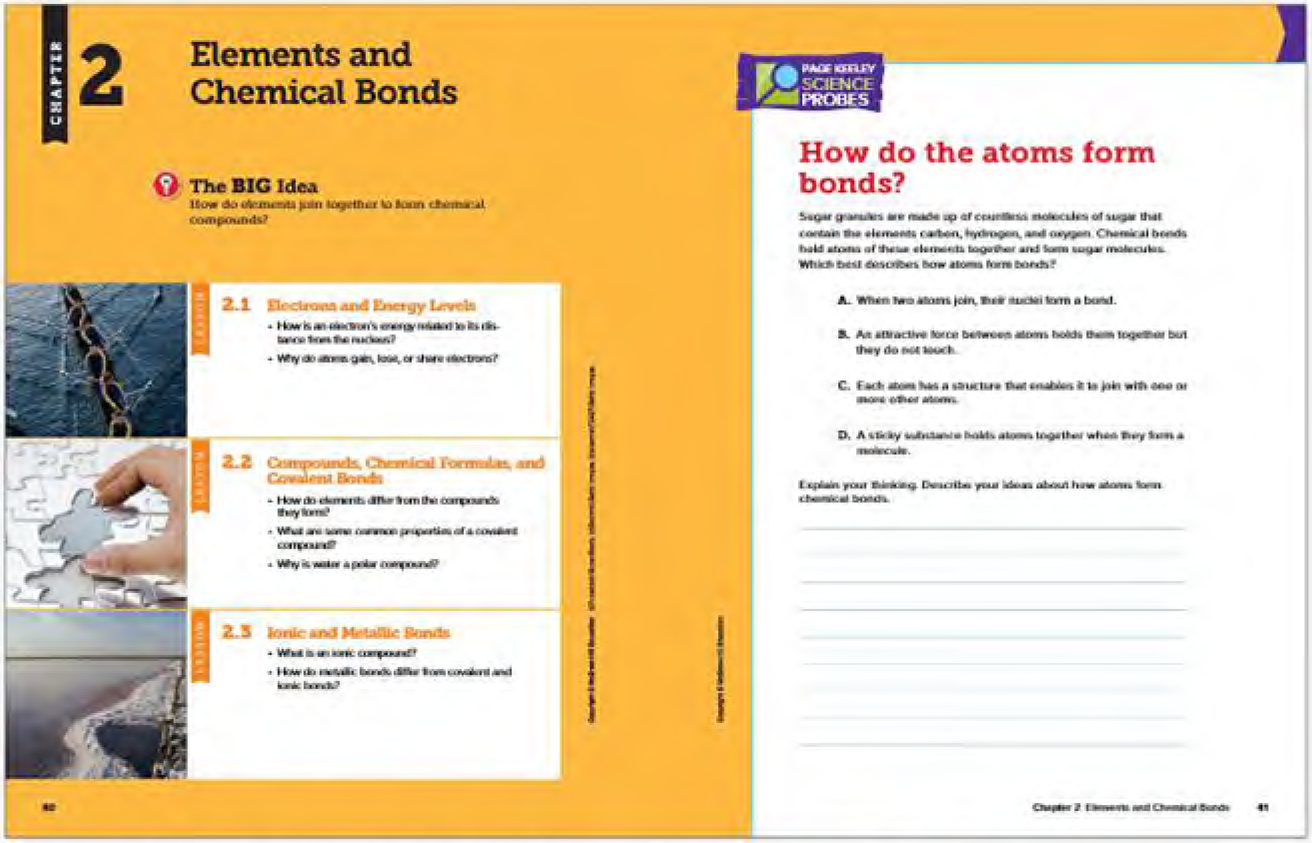
... atoms gain or lose electrons in a covalent bond or that atoms share electrons in an ionic bond. They may not understand the way valence electrons participate in each kind of bond or the kinds of elements that form these bonds.

Discussion

Remind students that when nonmetals form a bond, they share valence electrons. This is known as a covalent bond. However, when a nonmetal atom bonds with a metal atom, something different happens. The atoms gain or give up valence electrons in an ionic bond. Have students locate metals and nonmetals on the periodic table. **Ask:** What happens when elements on the right side of the periodic table combine? **They form a covalent bond.** **Ask:** What happens to valence electrons in a covalent bond? **The nonmetal atoms share valence electrons.** **Ask:** What happens when elements on the right side of the table combine with elements on the left? **They form an ionic bond.** **Ask:** What happens to valence electrons in an ionic bond? **The metal atom gives up its valence electrons to the nonmetal atom.**

Promote Understanding

Activity Have students make a poster that explains the differences between *covalent* and *ionic* bonds.



Elements and Chemical Bonds

The BIG Idea

There are no right or wrong answers to these questions. Write student-generated questions produced during the discussion on chart paper and return to them throughout the chapter.

Guiding Questions

AL **Think about the times you have worked on classroom assignments with a partner. How did working together help you complete the assignment?**	*This question initiates students' thinking about how things combine and how working in pairs can be more efficient than working alone, much like atoms sharing electrons.*
OL **Think about a band playing music. Each member of the band plays a different instrument. How is the song the band is playing together different from a musician playing alone?**	*This question initiates students' thinking about how things combine and how the sound of a group is different from the sound created by one musician, much like a compound is different from the elements that come together to create it.*
BL **Think about a sports team playing to win a game. Each athlete on the team plays a different position. How do you think working together helps them accomplish this goal?**	*This question initiates students' thinking about how things combine and how each member contributes to the whole team, much like the different elements that come together to form a compound.*

PAGE KEELEY SCIENCE PROBES

How do the atoms form bonds

Answers to the Page Keeley Science Probe can be found in the Teacher's Edition of the *Activity Lab Workbook.*

Get Ready to Read

What do you think?

Use this anticipation guide to gauge students' background knowledge and preconceptions about the elements and chemical bonds. At the end of the chapter, ask students to read and evaluate their earlier responses. Students should be encouraged to change any of their responses.

Anticipation Set for Lesson 1

1. **Elements rarely exist in pure form. Instead, combinations of elements make up most of the matter around you.**

   Agree. Most of the materials around you are substances that have been made from a combination of two or more elements.

2. **Chemical bonds that form between atoms involve electrons.**

   Agree. Chemical bonds that form between atoms only involve electrons.

Anticipation Set for Lesson 2

3. **The atoms in a water molecule are more chemically stable than the atoms would be individually.**

   Agree. A hydrogen atom has only one valence electron and an oxygen atom has six valence electrons. This makes them unstable. When two hydrogen atoms and an oxygen atom combine, they share two pairs of valence electrons. This gives them the electron arrangement of a noble gas and makes them stable.

4. **Many substances dissolve easily in water because opposite ends of a water molecule have opposite charges.**

   Disagree. Only other polar compounds dissolve easily in water because opposite ends of a water molecule have opposite charges.

Anticipation Set for Lesson 3

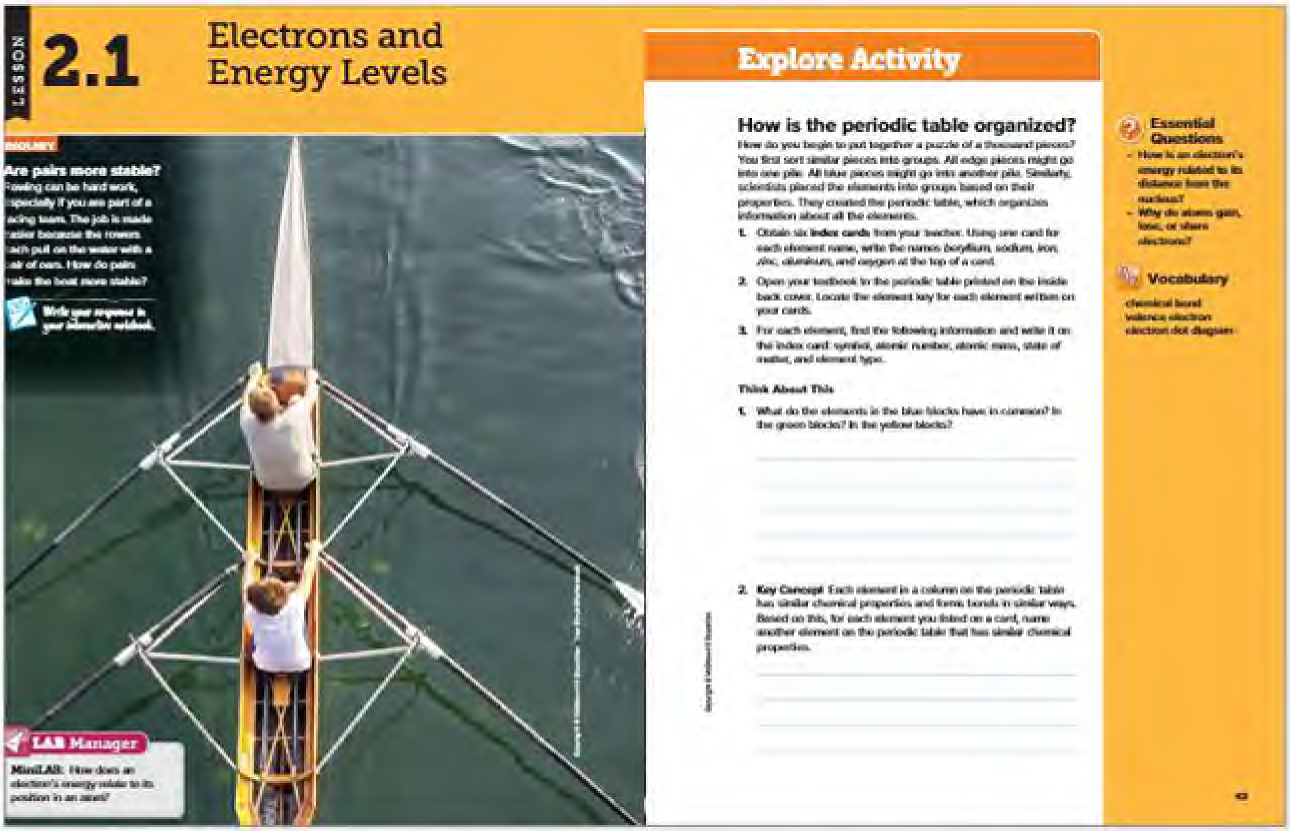
5. **Losing valence electrons can make some atoms more chemically stable.**

   Agree. If an atom only has one valence electron, losing it gives the atom the electron arrangement of a noble gas, which makes it stable.

6. **Metals are good electrical conductors because they tend to hold onto their valence electrons very tightly.**

   Disagree. Metals are good electrical conductors because their valence electrons can easily move from atom to atom.

Teacher Notes


LESSON 2.1 Electrons and Energy Levels

INQUIRY

Are pairs more stable?

LAB Manager

MiniLAB: How does an electron's energy relate to its position in an atom?

Explore Activity

How is the periodic table organized?

Think About This

Essential Questions

Vocabulary

INQUIRY

About the Photo This racing team works together to row their boat. The leader, or coxswain, calls out directions to help his teammates row together and at the same pace. Each of the four rowers has a pair of oars, for a total of eight. The oars not only push the boat forward; they also keep it steady and prevent it from rocking from side to side.

Guiding Questions

AL **What do you think would happen to the boat if one of the members of the team lost an oar?**	*The boat would become less stable and might drift to one side.*
OL **How do you think the boat would move if each rower only had one oar?**	*The boat would still move, but the movement would be slower and less organized.*
BL **How does the sidewinder move so that it makes a series of grooves in the sand?**	*No; if the team only had one or two oars, the boat would be less stable and would move much more slowly and less efficiently.*

LAB Manager

Labs can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Key Concepts and be able to answer these questions. Have students write each question in their Science Journals. Revisit each question as you cover its relevant content.

Vocabulary

Everyday Bonds

1. Explain to students that one definition of the word bond is "something that holds or fastens things together." Then discuss with the class some of the different ways to create bonds between objects, such as gluing pieces of paper together, tying two strings, or sewing two pieces of cloth. Have students explore whether these bonds are temporary or permanent.
2. **Ask: Is it possible to undo these kinds of bonds?**
3. Ask students to consider how a chemical bond might be the same or different from the everyday definition of the word bond.

Explore Activity

How is the periodic table organized?

Prep: 5 *min* **Class:** 10 *min*

Purpose
To learn how the periodic table and the information it contains is arranged.

Materials
six index cards per student or group, textbook

Before You Begin
Have students read the first paragraph in **The Periodic Table**.

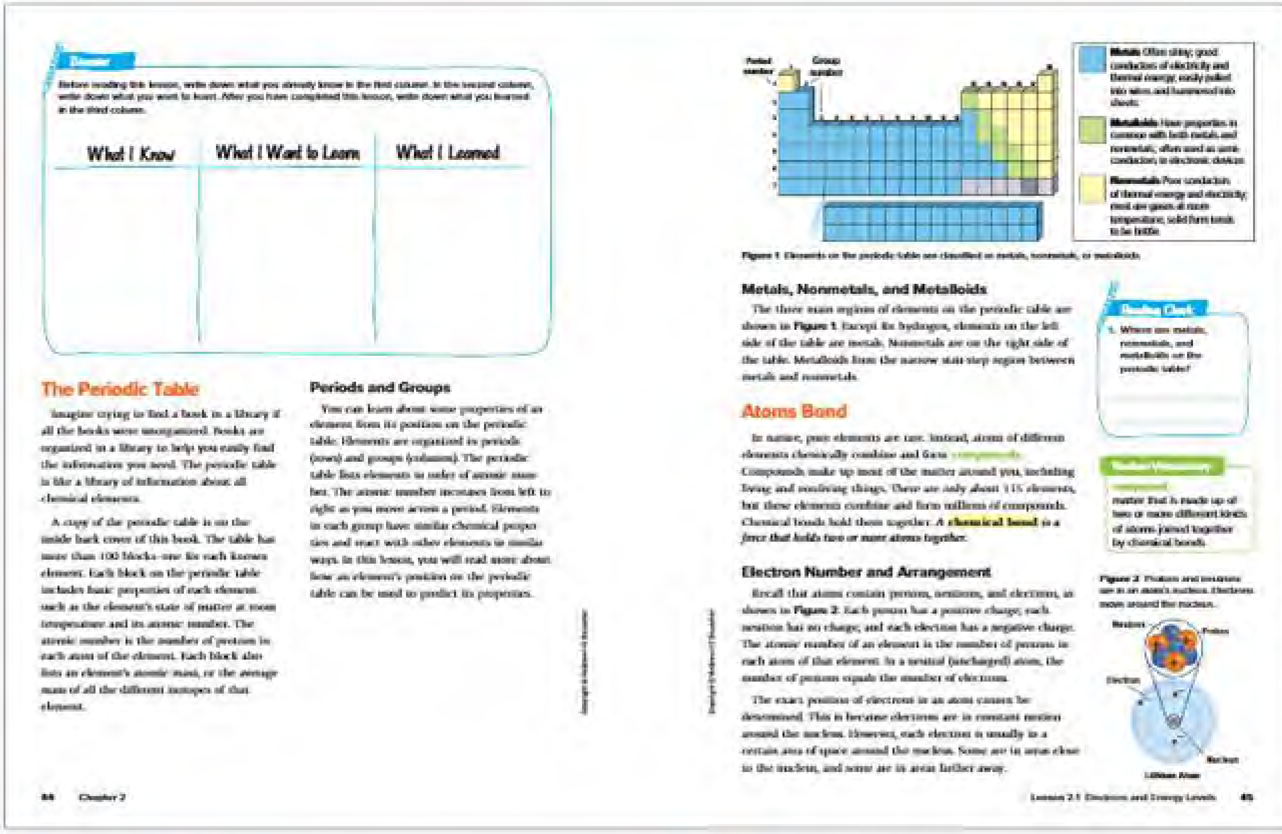
Guide the Investigation

- Have students recall searching for a book at the library. Ask them what is the most important information they need to know about a book in order to identify it. Ask them to speculate about ways a library could organize all the books to make it easy for people to find the books they need.
- Show students where the periodic table is on the inside back cover of the text. Point out where the keys are on the table.

Think About This

1. The elements in the blue blocks are metals and mostly solid. The elements in the green blocks are metalloids and are all solids. The elements in the yellow blocks are nonmetals and are mostly solids or gases except for bromine, which is a liquid.
2. **Key Concept** Answers will vary. Accept any response that includes an element found in the same column of the periodic table as the element written on the card. Possible answers: magnesium (similar to beryllium), ruthenium (similar to iron), and sulfur (similar to oxygen).

Teacher Notes



What I Know | What I Want to Learn | What I Learned

The Periodic Table

Periods and Groups

Metals, Nonmetals, and Metalloids

Atoms Bond

Electron Number and Arrangement

The Periodic Table

Have students turn to the inside back cover of the text and review the definition of *periodic table*. Remind them it is a chart in which elements are in rows and columns according to physical and chemical properties. Have students read the paragraphs and answer the following questions.

Guiding Questions

AL **What is the periodic table?**	*It is a chart that lists all the elements according to their physical and chemical properties.*
OL **What does each block on the periodic table list?**	*the name of an element, its symbol, its atomic number, and its atomic mass*
BL **How is an atomic number different from an atomic mass?**	*The atomic number is the number of protons in each atom of an element, while the atomic mass is the weighted average mass of all the isotopes of an element.*

Periods and Groups

Discuss with students how using the periodic table helped them complete the **Launch Lab**. Talk about where they found the atomic number and the atomic mass for each of the six elements.

Ask: **How is the periodic table organized?** *The periodic table organizes elements by increasing atomic number. The atomic number is the number of protons in an atom of an element.*

Metals, Nonmetals, and Metalloids

Discuss with students some of the ways people use color to arrange objects. For example, green vegetables are often stacked in the same row in the grocery store. Arranging by color makes it easier to spot similar things. Explain that the periodic table also uses color to arrange the elements into groups. Have students read the paragraph and look at **Figure 1**. Explain that hydrogen is grouped with metals because when it is in its solid form (which only occurs at extreme pressures) it takes on properties of a metal. Then use the following scaffolded questions to informally assess students' comprehension.

Guiding Questions

AL **What does the green color show on the periodic table?**	*It shows the group of metalloid elements.*
OL **Where are metals, nonmetals, and metalloids on the periodic table?**	*Metals are on the left side of the periodic table. Nonmetals are on the right side of the table. Metalloids form the narrow stair-step pattern between the metals and the nonmetals.*
BL **The suffix –oid means "like." Why do you think the elements that are shaded green on the periodic table are called metalloids?**	*They are called metalloids because they are somewhat like metals and have some physical and chemical properties in common with them.*

Atoms Bond

Explain that atoms can fasten or join together. Have students read the paragraph. Then ask the following scaffolded questions.

Guiding Questions

AL What do atoms create when they combine?	*compounds*
OL What is a chemical bond?	*A chemical bond is a force that holds two or more atoms together in a compound.*
BL Why do you think compounds make up most of the matter around us?	*There are only 115 known elements, but there are millions of different materials in the world. Therefore, these materials must be made from elements that have combined into different compounds.*

Review Vocabulary

compound

Explain that the different elements shown on the periodic table combine and form compounds.

Ask: **How does the number of compounds differ from the number of elements?** *There are millions of compounds but only 115 elements.*

Differentiated Instruction

AL **A Mobile of an Atom** Have students work in pairs to create a mobile that shows the particles inside an atom. It should include the nucleus and the electrons that move around it. Students should label each part of the mobile and if they need help, refer them to the diagrams shown in **Figure 2** and **Figure 3**.

BL **How do electrons behave?** Have students write a short story about electrons circling the nucleus of an atom. Some of the electrons should be close to the nucleus while others are farther away. Students' stories should describe the energy level of the electrons and their attraction to the nucleus.

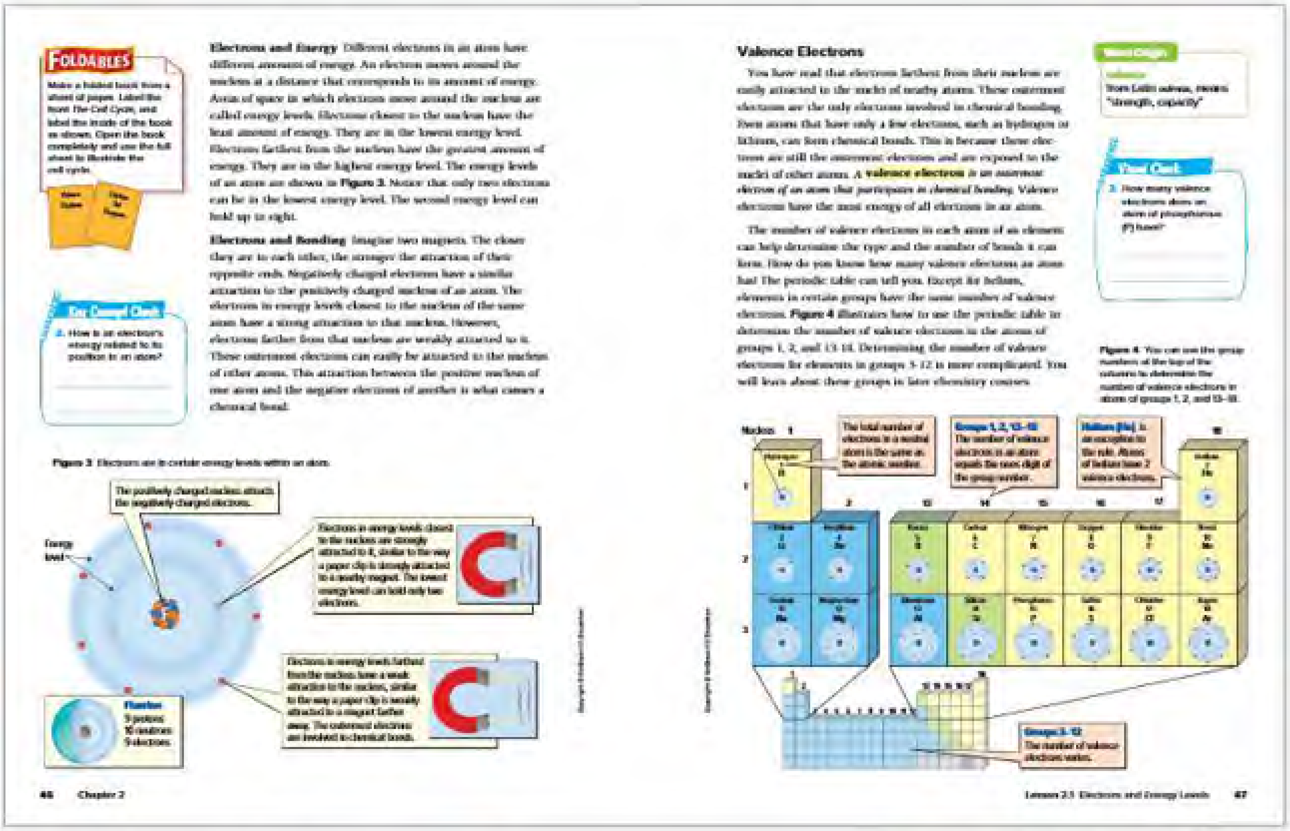
Teacher Toolbox

Fun Fact

Electrons and Distance Atoms are mostly made up of space because the distance between the nucleus and the electrons surrounding it is enormous, relatively speaking. Imagine if a nucleus were the size of a tennis ball. The whole atom would be as tall as the Empire State Building because the electrons on the outer rim would be far away.

Careers in Science

Particle Accelerator Physicists are scientists who use huge machines called particle accelerators to study tiny subatomic particles such as protons and electrons. Particle accelerators smash particles together, helping physicists learn more about how they interact and the energy they can create. The largest particle accelerator is part of a physics lab called CERN. It is seven stories tall and located in Switzerland.



Electrons and Energy Different electrons in an atom have different amounts of energy. An electron moves around the nucleus at a distance that corresponds to its amount of energy. Areas of space in which electrons move around the nucleus are called energy levels. Electrons closest to the nucleus have the least amount of energy. They are in the lowest energy level. Electrons farthest from the nucleus have the greatest amount of energy. They are in the highest energy level. The energy levels of an atom are shown in **Figure 3**. Notice that only two electrons can be in the lowest energy level. The second energy level can hold up to eight.

Electrons and Bonding Imagine two magnets. The closer they are to each other, the stronger the attraction of their opposite ends. Negatively charged electrons have a similar attraction to the positively charged nucleus of an atom. The electrons in energy levels closest to the nucleus of the same atom have a strong attraction to that nucleus. However, electrons farther from that nucleus are weakly attracted to it. These outermost electrons can easily be attracted to the nucleus of other atoms. This attraction between the positive nucleus of one atom and the negative electrons of another is what causes a chemical bond.

Figure 3 Electrons are in certain energy levels within an atom.

Valence Electrons

You have read that electrons farthest from their nucleus are easily attracted to the nuclei of nearby atoms. These outermost electrons are the only electrons involved in chemical bonding. Even atoms that have only a few electrons, such as hydrogen or lithium, can form chemical bonds. This is because these electrons are still the outermost electrons and are exposed to the nuclei of other atoms. A **valence electron** *is an outermost electron of an atom that participates in chemical bonding.* Valence electrons have the most energy of all electrons in an atom.

The number of valence electrons in each atom of an element can help determine the type and the number of bonds it can form. How do you know how many valence electrons an atom has? The periodic table can tell you. Except for helium, elements in certain groups have the same number of valence electrons. **Figure 4** illustrates how to use the periodic table to determine the number of valence electrons in the atoms of groups 1, 2, and 13–18. Determining the number of valence electrons for elements in groups 3–12 is more complicated. You will learn about these groups in later chemistry courses.

Figure 4 You can use the group numbers at the top of the columns to determine the number of valence electrons in atoms of groups 1, 2, and 13–18.

46 Chapter 2 — Lesson 2.1 Electrons and Energy Levels 47

Electron Number and Arrangement

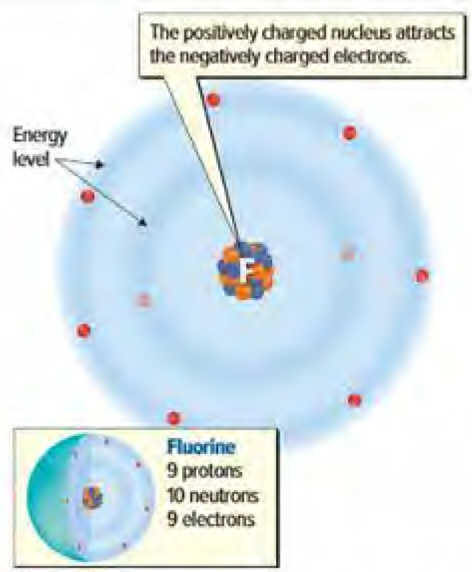
Remind students that electrons move around the nucleus of an atom in a cloud. Then have students look at **Figure 2** and read the paragraphs.

Guiding Questions

AL **Can the energy level closest to the nucleus hold three or more electrons? Why or why not?**	*No; the energy level closest to the nucleus can only hold two electrons.*
OL **How is an electron's energy related to its position in an atom?**	*Higher-energy electrons are farther away from the nucleus of an atom. Lower-energy electrons are closer to the nucleus.*
BL **Why are electrons farther away from a nucleus abl**	*They have a weak attraction to the nucleus so they are free to interact with other atoms.*

Visual Literacy: Electron Energy Levels

Students may need help understanding how distance affects both the energy level of the electrons and their attraction to the nucleus. Provide students with paper clips and small magnets. Have them hold the paper clip close to the magnet and then farther away to observe how the level of attraction changes. Then refer them to **Figure 3**. Use the following questions to help students analyze the diagram and assess their understanding.



Ask: **How many electrons are close to the nucleus inside this fluorine atom?** *two* **How many electrons are farther away?** *seven*

Ask: **How are the two electrons close to the nucleus different from the seven electrons that are farther away?** *They have a lower level of energy but a stronger attraction to the nucleus.*

Ask: Could some of the electrons that are farther away move closer to the nucleus? Why or why not? *No, because the energy level near the nucleus cannot hold more than two electrons.*

Valence Electrons

Remind students that the electrons that are farther away from the nucleus have a weaker attraction to it and are free to interact with other atoms. These electrons are like hands and can reach out to other atoms. Then ask the following questions.

Guiding Questions

AL **What kind of electron is free to participate in chemical bonding?**	*a valence electron*
OL **Why is it useful to know the number of valence electrons in an atom?**	*The number of valence electrons in an atom can be used to determine how many bonds are possible.*
BL **Which electron configuration do the elements in group 1 share?**	*They all have one valence electron and can form one chemical bond.*

Word Origin

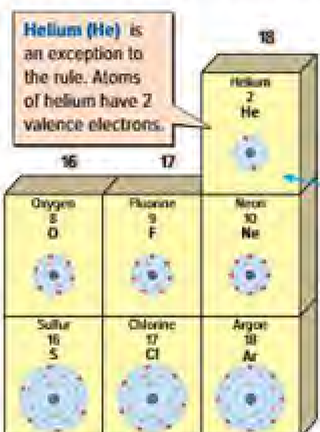
valence

Explain that the term *valence* comes from a Latin word that means "capacity." Tell students that another word for *capacity* is *ability*.

Ask: What are valence electrons able to do that other electrons cannot? *They are able to form chemical bonds.*

Visual Literacy: Periodic Table Groups

Have students find the shaded digit in the numbers at the top of each column in **Figure 4**. Explain that the ones digit is the number of valence electrons for each element in that group. For example, each element in the thirteenth column has three valence electrons.



Ask: Find neon (Ne) and helium (He) on the chart. Do they belong to the same group? *yes* **Do they have the same number of valence electrons? Why or why not?** *No; neon has eight valence electrons, but helium has only two.*

Ask: How many valence electrons does an atom of oxygen have? *six*

Differentiated Instruction

AL **Electron Dot Diagram** Have students work together in pairs to create an electron dot diagram for the elements selenium (Se) and krypton (Kr). They should use the periodic table on the inside back cover of their textbooks to create each diagram. If they need help, refer them to the chart in **Figure 5**. Have them write a caption beneath each diagram that names the element and explains how many valence electrons it has and how many bonds it can form.

BL **Sharing Electron Dot Diagrams** Have students choose four elements from rows 4–6 of the representative elements and groups 1–2 and 13–18 on the periodic table. They should create an electron dot diagram for each one. If they need help, refer them to the chart in **Figure 5**. Then have them exchange their diagrams with another student. They should take turns deciphering each other's diagrams to determine the name of the element, the number of valence electrons, and whether the atom is stable or unstable.

Teacher Toolbox

Fun Fact

The Valence Shell The outermost rim of an atom is also known as its valence shell. It is the area where the valence electrons orbit the nucleus. Some atoms, such as neon, have a full valence shell. Others, such as lithium, have a shell that is almost empty.

Real-World Science

Lewis Structures An American chemist named Gilbert N. Lewis was the first to create and use an electron dot diagram. He introduced the diagram in an article written in 1916 on atoms and molecules. Today, many scientists refer to the diagrams as Lewis structures.

Reading Strategy

Summarize Have students reread the section titled **Valence Electrons**. Ask them to write a short summary to explain what a valence electron is and the role it plays in chemical bonding. Remind them that summaries should primarily include the main ideas of a topic.

Electron Dot Diagrams

Before students read this page, recreate the electron dot diagram for fluorine on the board. **Ask: How many dots surround the F symbol?** *seven* **Ask: What is the number of valence electrons for fluorine on the periodic table?** *seven* Instruct students to read the section and consider what the dots on the diagram might represent. Use the following scaffolded questions to assess their comprehension.

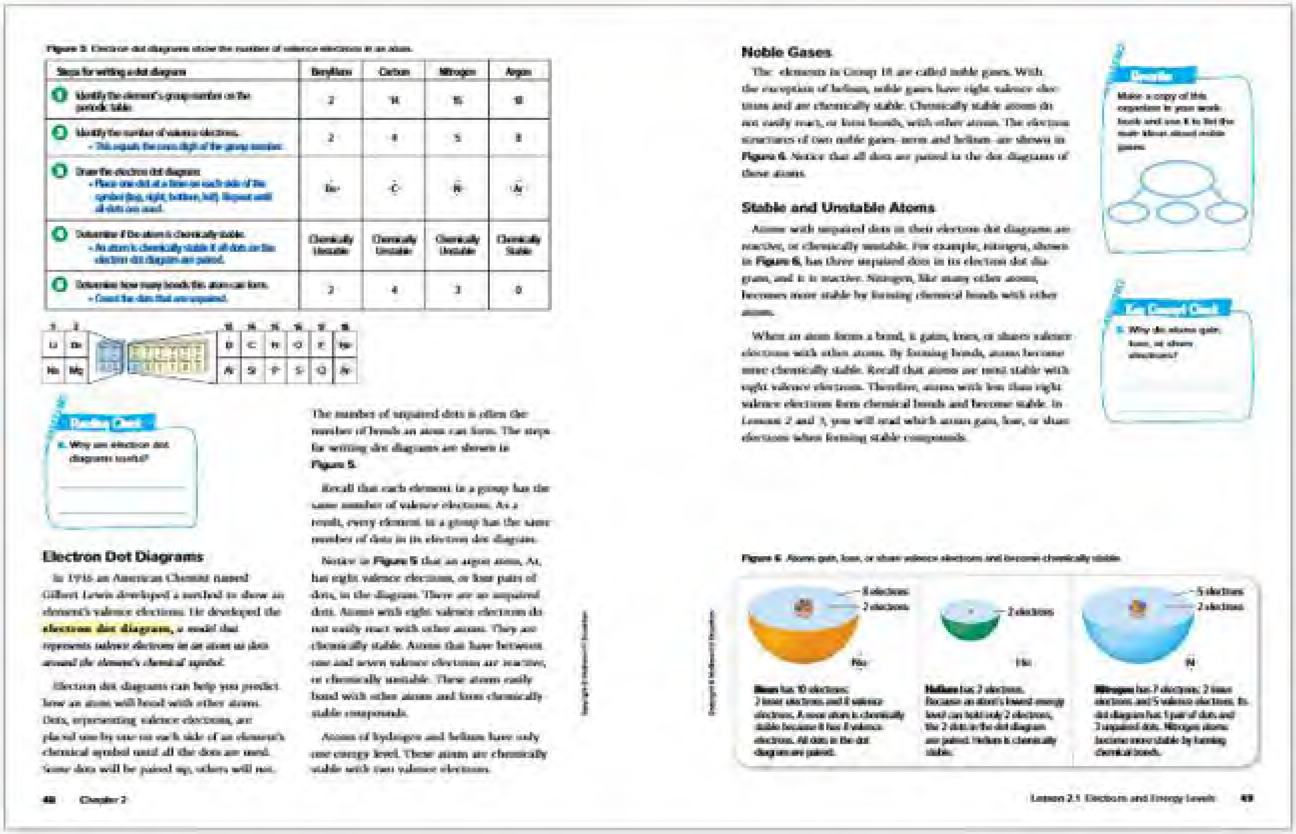


Figure 5 Electron dot diagrams show the number of valence electrons in an atom.

Steps for writing a dot diagram	Beryllium	Carbon	Nitrogen	Argon
1 Identify the element's group number on the periodic table.	2	14	15	18
2 Identify the number of valence electrons. • This equals the ones digit of the group number.	2	4	5	8
3 Draw the electron dot diagram. • Place one dot at a time on each side of the symbol (top, right, bottom, left). Repeat until all dots are used.	Be·	·C·	·N·	:Ar:
4 Determine if the atom is chemically stable. • An atom is chemically stable if all dots on the electron dot diagram are paired.	Chemically Unstable	Chemically Unstable	Chemically Unstable	Chemically Stable
5 Determine how many bonds this atom can form. • Count the dots that are unpaired.	2	4	3	0

Reading Check

4. Why are electron dot diagrams useful?

Electron Dot Diagrams

In 1916 an American Chemist named Gilbert Lewis developed a method to show an element's valence electrons. He developed the **electron dot diagram,** a model that represents valence electrons in an atom as dots around the element's chemical symbol.

Electron dot diagrams can help you predict how an atom will bond with other atoms. Dots, representing valence electrons, are placed one by one on each side of an element's chemical symbol until all the dots are used. Some dots will be paired up, others will not.

The number of unpaired dots is often the number of bonds an atom can form. The steps for writing dot diagrams are shown in **Figure 5.**

Recall that each element in a group has the same number of valence electrons. As a result, every element in a group has the same number of dots in its electron dot diagram.

Notice in **Figure 5** that an argon atom, Ar, has eight valence electrons, or four pairs of dots, in the diagram. There are no unpaired dots. Atoms with eight valence electrons do not easily react with other atoms. They are chemically stable. Atoms that have between one and seven valence electrons are reactive, or chemically unstable. These atoms easily bond with other atoms and form chemically stable compounds.

Atoms of hydrogen and helium have only one energy level. These atoms are chemically stable with two valence electrons.

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Noble Gases

The elements in Group 18 are called noble gases. With the exception of helium, noble gases have eight valence electrons and are chemically stable. Chemically stable atoms do not easily react, or form bonds, with other atoms. The electron structures of two noble gases–neon and helium–are shown in **Figure 6.** Notice that all dots are paired in the dot diagrams of these atoms.

Stable and Unstable Atoms

Atoms with unpaired dots in their electron dot diagrams are reactive, or chemically unstable. For example, nitrogen, shown in **Figure 6,** has three unpaired dots in its electron dot diagram, and it is reactive. Nitrogen, like many other atoms, becomes more stable by forming chemical bonds with other atoms.

When an atom forms a bond, it gains, loses, or shares valence electrons with other atoms. By forming bonds, atoms become more chemically stable. Recall that atoms are most stable with eight valence electrons. Therefore, atoms with less than eight valence electrons form chemical bonds and become stable. In Lessons 2 and 3, you will read which atoms gain, lose, or share electrons when forming stable compounds.

Make a copy of this organizer in your work book and use it to list the main ideas about noble gases.

Key Concept Check

5. Why do atoms gain, lose, or share electrons?

Figure 6 Atoms gain, lose, or share valence electrons and become chemically stable.

Neon has 10 electrons: 2 inner electrons and 8 valence electrons. A neon atom is chemically stable because it has 8 valence electrons. All dots in the dot diagram are paired.

Helium has 2 electrons. Because an atom's lowest energy level can hold only 2 electrons, the 2 dots in the dot diagram are paired. Helium is chemically stable.

Nitrogen has 7 electrons: 2 inner electrons and 5 valence electrons. Its dot diagram has 1 pair of dots and 3 unpaired dots. Nitrogen atoms become more stable by forming chemical bonds.

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Guiding Questions

AL What do the dots on an electron dot diagram represent?	*They represent the number of valence electrons in an atom.*
OL Why are electron dot diagrams useful?	*An electron dot diagram shows the paired and unpaired valence electrons of an atom.*
BL Look at the chart in Figure 4. Would an electron dot diagram for oxygen (O) have the same number of dots as a diagram for sulfur (S)? Why or why not?	*Yes; both elements belong to the same group and have the same number of valence electrons.*
BL How are unstable atoms different from stable atoms?	*Atoms with eight valence electrons are stable. Elements with fewer than eight electrons are unstable. Hydrogen is an exception—it is stable with two electrons and unstable with one electron.*

Visual Literacy: Writing and Using Electron Dot Diagrams

Students may need help to understand how to create an electron dot diagram, and how they demonstrate which atoms are chemically stable and which are unstable. Refer them to **Figure 5.** Tell them that each symbol has four sides, like a square. The dots that surround it are placed alone if the element has fewer than five valence electrons or in as many pairs as possible if it has five or more valence electrons. Use the following questions to walkthrough the process.

13	14	15	16	17	18
B·	·C·	·N·	·O:	·F:	:Ne:
Al·	·Si·	·P·	·S:	·Cl:	:Ar:

Ask: What are the first two steps in creating an electron dot diagram? *Write the symbol for the element and find the number of valence electrons it has.*

Ask: How is an argon atom similar to the photo of the racing boat on the lesson opener page? *An argon atom has eight paired valence electrons, which keeps it stable. The boat has eight paired oars, which keeps it stable.*

Ask: How do you represent the number of valence electrons in the dot diagram? *Place one dot at a time on each side of the symbol until all the valence electrons are represented on the diagram.*

Noble Gases

Have students turn to the periodic table on the inside back cover of the text. Ask them to locate the elements in column 18. Then have them read the paragraph and use the following scaffolded questions to informally assess their comprehension of this concept.

Guiding Questions

AL **What group of elements is located in column 18?**	*noble gases*
OL **How does helium (He) differ from the elements in its group?**	*Helium has two valence electrons instead of eight.*
BL **Do the elements in group 18 have stable or unstable atoms? Explain.**	*They have stable atoms because all the valence eletrons are paired and will not bond easily with other elements.*

Stable and Unstable Atoms

Have students read the paragraph and study **Figure 6**. Use the following scaffolded questions to assess their comprehension of this concept.

Guiding Questions

AL **How can unstable atoms become stable?**	*They can form bonds with other atoms.*
OL **Why do atoms gain, lose, or share electrons?**	*An atom gains, loses, or shares electrons to become chemically stable.*

Teacher Toolbox

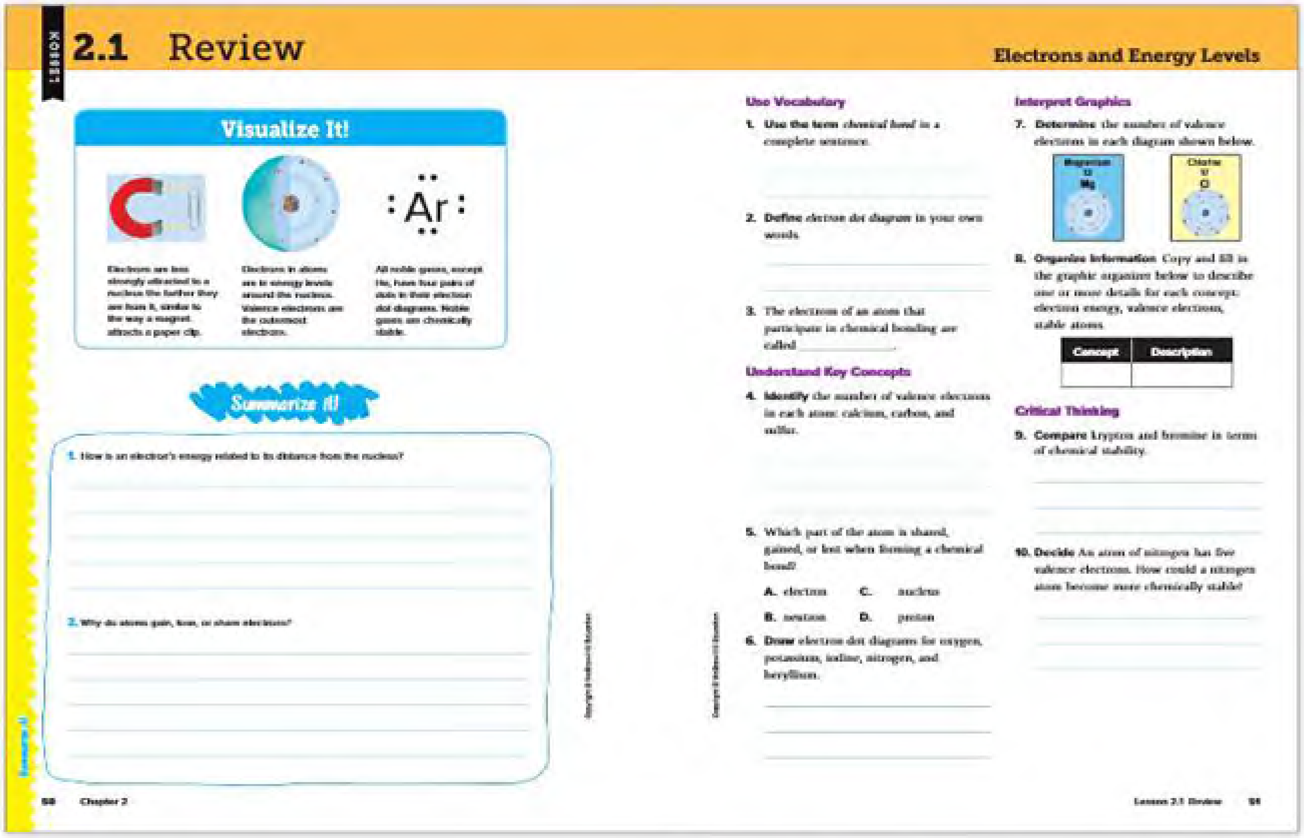
Fun Fact

Common Carbon Carbon is one of the most common elements in the world and is in many different compounds. People eat foods that contain carbon, wear clothing with carbon, and even have carbon in their bodies. That is because carbon atoms are very unstable and can form four different bonds. So, it is no wonder this element can be found almost everywhere!

Real-World Science

The Helium Exception Helium is an exception among the noble gases because it has a total of two electrons altogether. Therefore, it could not have eight valence electrons like the other elements in its group. However, it is included with the noble gases because it has other properties in common with those elements: They are all odorless and colorless and have full energy levels.

AL Approaching Level OL On Level BL Beyond Level



LESSON

2.1 Review

Electrons and Energy Levels

Visualize It!

Electrons are less strongly attracted to a nucleus the farther they are from it, similar to the way a magnet attracts a paper clip.

Electrons in atoms are in energy levels around the nucleus. Valence electrons are the outermost electrons.

All noble gases, except He, have four pairs of dots in their electron dot diagrams. Noble gases are chemically stable.

Summarize It!

1. How is an electron's energy related to its distance from the nucleus?

2. Why do atoms gain, lose, or share electrons?

Use Vocabulary

1. **Use the term** *chemical bond* in a complete sentence.

2. **Define** *electron dot diagram* in your own words.

3. The electrons of an atom that participate in chemical bonding are called ________.

Understand Key Concepts

4. **Identify** the number of valence electrons in each atom: calcium, carbon, and sulfur.

5. Which part of the atom is shared, gained, or lost when forming a chemical bond?

A. electron C. nucleus

B. neutron D. proton

6. **Draw** electron dot diagrams for oxygen, potassium, iodine, nitrogen, and beryllium.

Interpret Graphics

7. **Determine** the number of valence electrons in each diagram shown below.

8. **Organize Information** Copy and fill in the graphic organizer below to describe one or more details for each concept: electron energy, valence electrons, stable atoms.

Concept	Description

Critical Thinking

9. **Compare** krypton and bromine in terms of chemical stability.

10. **Decide** An atom of nitrogen has five valence electrons. How could a nitrogen atom become more chemically stable?

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Lesson 2.1 Review 51

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Ask: Which Key Concept does each image relate to?**

Summarize It!

The information needed to complete this graphic organizer can be found in the following sections:

- Atoms Bond

Use Vocabulary

1. Possible answer: A chemical bond forms when two hydrogen atoms and one oxygen atom share electrons to make water molecules.

2. Possible answer: An electron dot diagram is a model that arranges electrons, as dots, around the element symbol of an atom.

3. valence electrons

Understand Key Concepts

4. calcium: 2; carbon: 4; sulfur: 6

5. A. electron

6. The electron dot diagrams should show these chemical symbols and numbers of dots: oxygen, O, 6; potassium, K, 1; iodine, I, 7; nitrogen, N, 5; beryllium, Be, 2.

Interpret Graphics

7. Magnesium has 2 valence electrons and chlorine has 7 valence electrons.

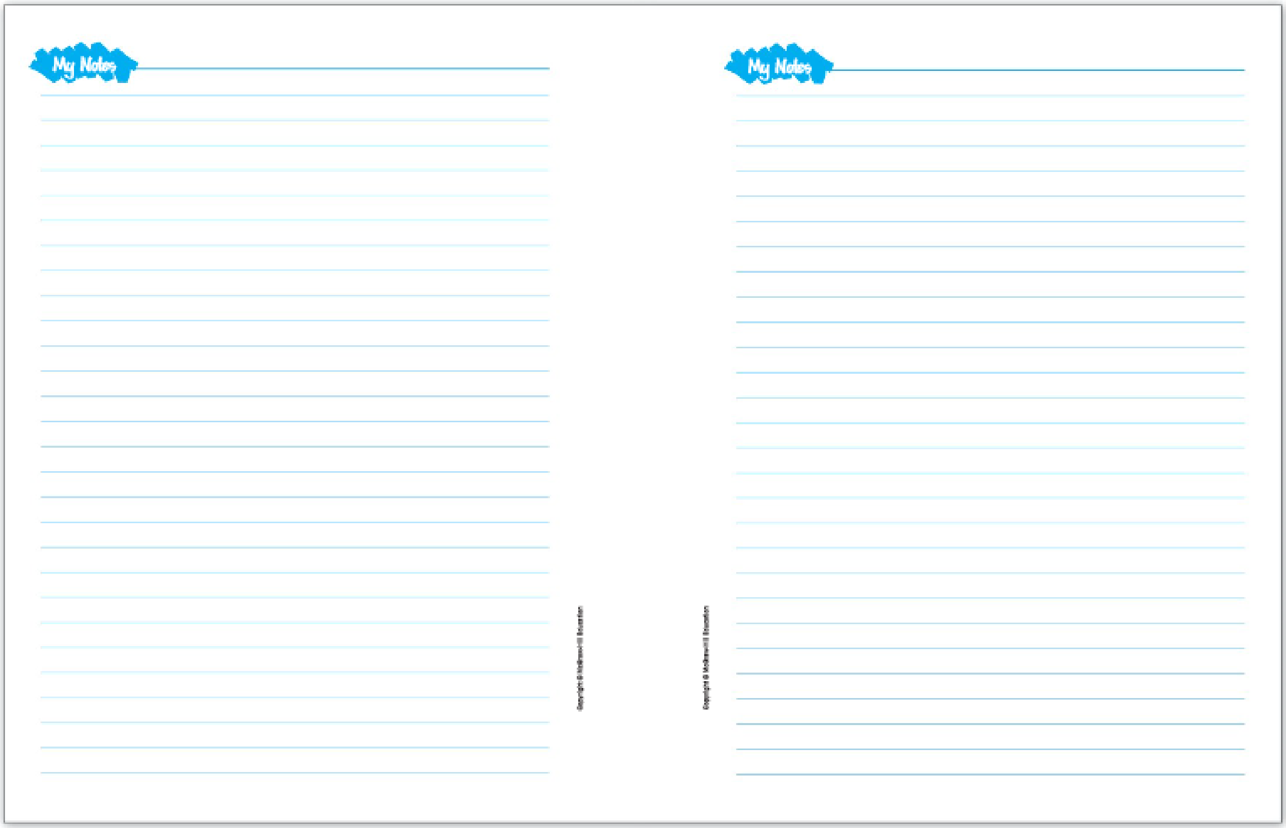
8.

Concept	Description
Electron energy	An electron's distance from the nucleus corresponds to its electron energy. Electrons close to the nucleus have the least energy. Electrons far from the nucleus have the greatest energy.
Valence electrons	Valence electrons are the outermost electrons of an atom that participate in chemical bonding.
Stable atoms	Atoms with valence electron arrangements similar to the noble gases are considered chemically stable.

Critical Thinking

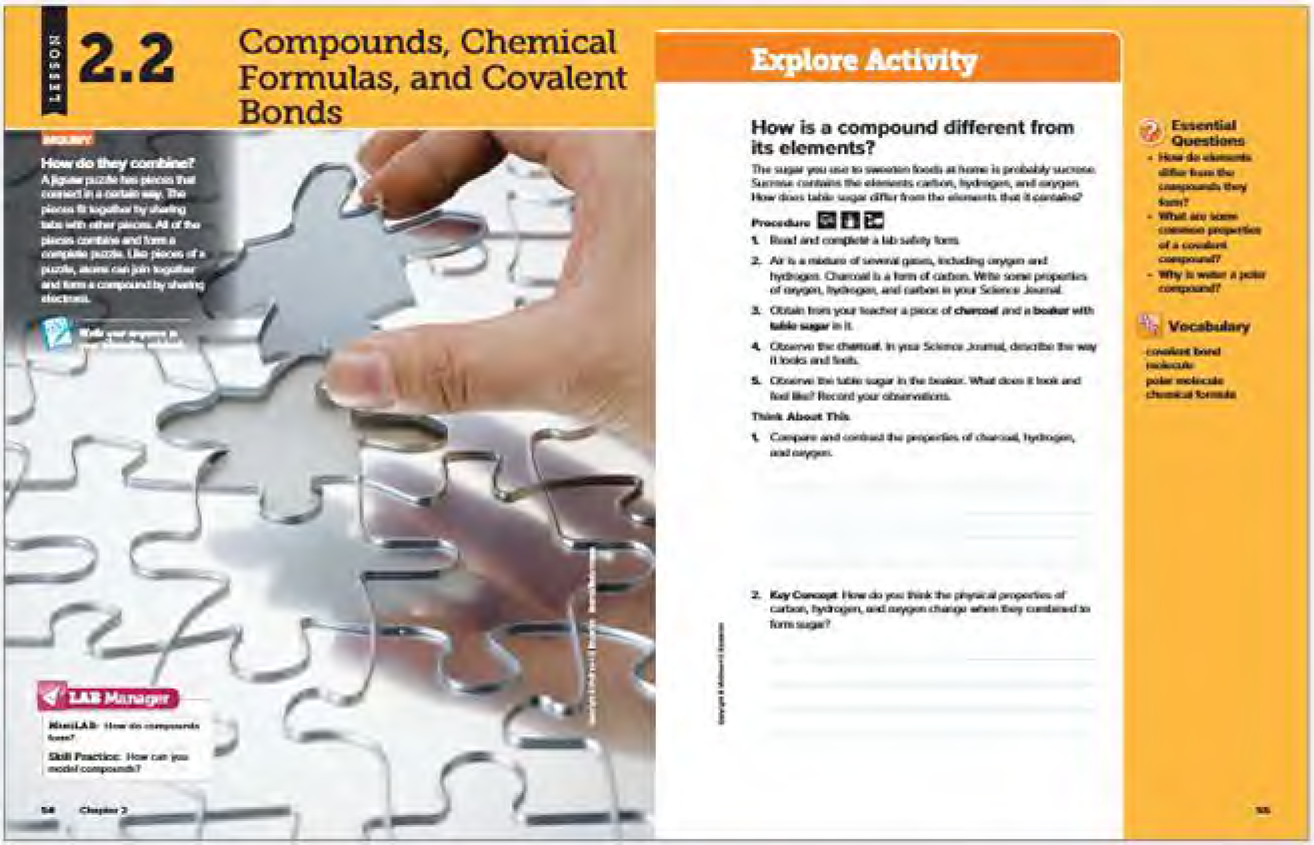
9. Possible answer: Krypton is more stable than bromine because an atom of krypton has eight valence electrons, or four pairs of dots in the dot diagram. Bromine has seven valence electrons and one unpaired dot in the dot diagram.
10. Nitrogen would achieve chemical stability when it gains or shares three valence electrons giving it a stable noble gas configuration.

Teacher Notes


My Notes

My Notes

Teacher Notes



INQUIRY

About the Photo How do they combine? Each piece of a puzzle has a unique shape. The pieces fit together and form a puzzle. Once a puzzle has been put together, it looks very different from all the pieces that were used to create it.

Guiding Questions

AL How do puzzle pieces join together? How do atoms join together?	*Puzzle pieces join together when the tab of one piece fits into the slot of another. Atoms join together when they share valence electrons.*
OL How are puzzle pieces similar to atoms?	*They both make connections and create something. Puzzle pieces connect with one another and complete an image. Atoms connect with one another and create new materials.*
BL Which part of a puzzle piece is similar to the valence electrons in an atom?	*The tabs of a puzzle piece are like valence electrons. They bind with other pieces that have an empty slot to match.*

LAB Manager

Labs can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Key Concepts and be able to answer these questions. Have students write each question in their Science Journals. Revisit each question as you cover its relevant content.

Vocabulary

Create a Dictionary Entry

1. Write the word *formula* on chart paper or on the board. Have students look up the different meanings of the word in the dictionary. Discuss how they might use the word in an everyday context.
2. Have students work together as a class to create a dictionary entry for the term, writing two or three of the definitions they found in their own words.
3. Have students record the dictionary entry in their Science Journals. After they have completed the lesson, have them compare their definitions to the scientific definition of the term *chemical formula*. Ask students to consider how the scientific definition is similar to or different from the everyday definitions.

Explore Activity

How is a compound different from its elements?

Prep: *5 min* **Class:** *20 min*

Purpose
To observe how the elements that make up a chemical compound have different physical properties than the compound.

Materials
charcoal (any form: blocks, lump, sticks), table sugar, beaker (any size)

Before You Begin
The charcoal can be purchased at grocery, home improvement, or aquarium supply stores. Use granulated sugar instead of sugar cubes.
For each group of students, place about 50 mL of charcoal in one 100-mL beaker and about 50 mL of table sugar in another 100-mL beaker.

Think About This

1. The charcoal is a black solid. The hydrogen and oxygen gases are odorless and colorless.
2. **Key Concept** The black, solid charcoal and odorless, colorless gases chemically combined to create a white crystalline solid. Make sure students do not have the misconception that sugar forms from the combination of charcoal and gases from the air..

Teacher Notes

Before reading this lesson, write down what you already know in the first column. In the second column, write down what you want to learn. After you have completed this lesson, write down what you learned in the third column.

What I Know	What I Want to Learn	What I Learned

Key Concept Check

1. How is a compound different from the elements that compose it?

Science Use v. Common Use

bond

Science Use a force that holds atoms together in a compound

Common Use a close personal relationship between two people

From Elements to Compounds

Have you ever baked cupcakes? First, combine flour, baking soda, and a pinch of salt. Then, add sugar, eggs, vanilla, milk, and butter. Each ingredient has unique physical and chemical properties. When you mix the ingredients together and bake them, a new product results—cupcakes. The cupcakes have properties that are different from the ingredients.

In some ways, compounds are like cupcakes. Recall that a compound is a substance made up of two or more different elements. Just as cupcakes are different from their ingredients, compounds are different from their elements. An element is made of one type of atom, but compounds are chemical combinations of different types of atoms. Compounds and the elements that make them up often have different properties.

Chemical bonds join atoms together. Recall that a chemical bond is a force that holds atoms together in a compound. In this lesson, you will learn that one way that atoms can form bonds is by sharing valence electrons. You will also learn how to write and read a chemical formula.

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Figure 2 A covalent bond forms when two nonmetal atoms share electrons.

Covalent Bonds—Electron Sharing

As you read in Lesson 1, one way that atoms can become more chemically stable is by sharing valence electrons. When unstable, nonmetal atoms bond together, they bond by sharing valence electrons. A **covalent bond** *is a chemical bond formed when two atoms share one or more pairs of valence electrons.* The atoms then form a stable covalent compound.

A Noble Gas Electron Arrangement

Look at the reaction between hydrogen and oxygen in **Figure 2**. Before the reaction, each hydrogen atom has one valence electron. The oxygen atom has six valence electrons. Recall that most atoms are chemically stable with eight valence electrons—the same electron arrangement as a noble gas. An atom with less than eight valence electrons becomes stable by forming chemical bonds until it has eight valence electrons. Therefore, an oxygen atom forms two bonds to become stable. A hydrogen atom is stable with two valence electrons. It forms one bond to become stable.

Shared Electrons

If the oxygen atom and each hydrogen atom share their unpaired valence electrons, they can form two covalent bonds and become a stable covalent compound. Each covalent bond contains two valence electrons—one from the hydrogen atom and one from the oxygen atom. Since these electrons are shared, they count as valence electrons for both atoms in the bond. Each hydrogen atom now has two valence electrons. The oxygen atom now has eight valence electrons, since it bonds to two hydrogen atoms. All three atoms have the electron arrangement of a noble gas and the compound is stable.

FOLDABLES

Make three quarter-sheet note cards from a sheet of paper to organize information about single, double, and triple covalent bonds.

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From Elements to Compounds

Inform students that ingredients, such as flour, eggs, milk, and butter, often are used to make cupcakes. Ask students to describe these ingredients and then compare those descriptions with a cupcake. Ask students to discuss their experiences with the Launch Lab and describe some of their findings. Have them read the paragraphs and answer these questions.

Guiding Questions

OL **How is a compound different from the elements that compose it?**	*A compound has different chemical and physical properties than each of its individual elements.*
BL **How are compounds like cupcakes?**	*Compounds are made of different materials, like cupcakes. They also have properties that are different from the elements used to make them.*

Science Use v. Common Use

bond

Explain that people also form bonds. Discuss some of the personal relationships that people form, such as the bond between friends, parents and children, or teachers and students.

Ask: How is a bond between people similar to a chemical bond? *People form connections that bring them together just as atoms form connections that bring them together.*

Covalent Bonds—Electron Sharing

Have students turn to the inside back cover of their textbooks once again to study the periodic table. Ask them to locate the nonmetals on the chart. If they need help, refer them to **Figure 1** in **Lesson 1.** Then have students read the paragraph. After they read, use the following scaffolded questions to informally assess their comprehension of this concept.

Guiding Questions

AL **What happens when atoms share electrons?**	*They form a chemically stable compound.*
OL **What happens when a nonmetal element bonds with another nonmetal?**	*They form one or more covalent bonds by sharing one or more pairs of valence electrons.*

A Noble Gas Electron Arrangement

Have students locate the noble gases in group 18 of the periodic table. Remind them that these elements are stable because they have eight valence electrons. Unstable atoms become stable when they have a similar electron arrangement. Then have students read the paragraph.

Visual Literacy: Covalent Bonds

Have students study **Figure 7** to understand how hydrogen and oxygen atoms form covalent bonds and create water. Remind them that hydrogen atoms only have one energy level. As a result, they can only hold two electrons at most. Therefore, each hydrogen atom shares only one valence electron with the oxygen atom to become stable. Use the following questions to help students analyze the diagram and assess their understanding.

Ask: **How many valence electrons does an unstable oxygen atom have?** *six* **How many valence electrons does it share with the two hydrogen atoms?** *two* **How many valence electrons does a stable oxygen atom have after forming covalent bonds with hydrogen atoms?** *eight*

Shared Electrons

Have students read the paragraph. After they read, use the following scaffolded questions to informally assess their comprehension of this concept.

Guiding Questions

AL **What kind of bond holds hydrogen and oxygen atoms together when they combine?**	*a covalent bond*
BL **How does a covalent bond help an unstable atom become stable?**	*When unstable atoms form a covalent bond, they share valence electrons so the atoms become stable.*

Double and Triple Covalent Bonds

Have students read the paragraph and study **Figure 8**. Some students may confuse the number of valence electrons with the number of bonds. Explain that although there are more valence electrons in a carbon dioxide molecule than in a nitrogen molecule, the atoms in carbon dioxide only share two pairs of valence electrons and become stable. Ask the following scaffolded questions to assess their comprehension of this concept.

Guiding Questions

AL **Why is nitrogen an example of a triple covalent bond?**	*In a nitrogen molecule, the atoms share three pairs of valence electrons.*
OL **Is the bond stronger between atoms in hydrogen gas (H_2) or nitrogen gas (N_2)? Why?**	*The bond is stronger between atoms of nitrogen gas because a molecule of N_2 contains a triple bond, which involves three shared pairs of valence electrons. H_2 contains a single bond, which involves one shared pair of valence electrons.*
BL **Look at the diagram of a water molecule in Figure 7. What kind of covalent bond does it show? Explain your answer.**	*It shows two single covalent bonds because each atom in a water molecule shares one pair of valence electrons.*

Differentiated Instruction

AL **A Mobile of a Molecule** Have students make a mobile of a water molecule. They should include an oxygen atom and two hydrogen atoms. If they need help, refer them to **Figure 7**.

BL **Covalent Bond Poster** Have students create a poster with diagrams or illustrations that explain what a covalent bond is, the kinds of atoms that form covalent bonds, and the way that valence electrons participate in a covalent bond.

Teacher Toolbox

Teacher Demo

Mixing Clay Bring to class two small pieces of clay that are different colors.

1. Have students observe as you press the clay together to make a bigger piece that is a mix of the two colors.
2. Ask: How is this new piece of clay different from the original two pieces? It is bigger and contains multiple colors.
3. Ask: How is that similar to what happens when atoms combine? When the pieces of clay combine, they create something new that has different properties from the original ingredients, just as compounds have different properties from the atoms that create them.

Real-World Science

What makes salt? Salt is a common compound many people use every day. You might be surprised to learn how different it is from the elements that create it. Salt is made of sodium, which is a silvery metal, and chlorine is a poisonous green gas. It might be hard to believe that when those two elements combine, they create salt!

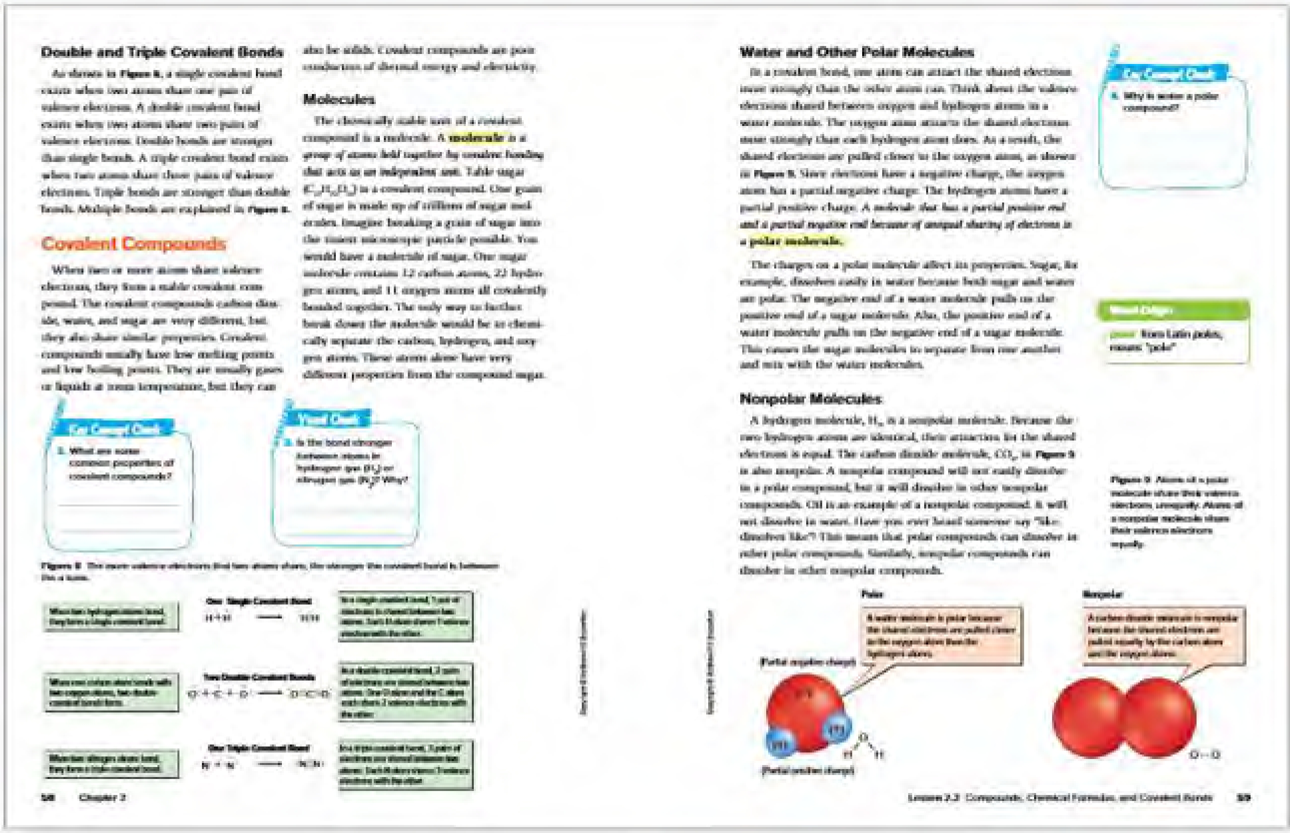
Covalent Compounds

Hold up two glasses for your students to observe—one should be filled with sugar and the other with water. Ask students to describe the two substances and compare their properties. For example, water is a liquid at room temperature, while sugar is a solid.

Write the formula for water (H_2O) on chart paper or the board. Explain that it shows all the atoms in a molecule of water. If you divided this molecule into the three separate atoms, it would no longer be water.

Guiding Questions

AL **In which state are most covalent compounds at room temperature?**	*gases or liquids*
OL **What are some common properties of covalent compounds?**	*Common properties of covalent compounds include having low melting points and low boiling points, existing as a gas or a liquid at room temperature, and serving as poor conductors of thermal energy and electricity.*
BL **What would happen to a sugar molecule if you chemically separated the different parts?**	*It would divide into different elements and would no longer be sugar.*


Double and Triple Covalent Bonds

Covalent Compounds

Molecules

Key Concept Check
5. What are some common properties of covalent compounds?

Visual Check
6. Is the bond stronger between atoms in hydrogen gas (H_2) or nitrogen gas (N_2)? Why?

Water and Other Polar Molecules

Key Concept Check
8. Why is water a polar compound?

Word Origin
polar from Latin polus, means "pole"

Nonpolar Molecules

Figure 9 Atoms of a polar molecule share their valence electrons unequally. Atoms of a nonpolar molecule share their valence electrons equally.

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Water and Other Polar Molecules

Tell students that some molecules have an unequal distribution of charges and one part of the molecule might be slightly more positive and another part might be slightly more negative. This is often due to the size of the atoms bonded together in the molecule. Have the students read the paragraphs and answer the following scaffolded questions.

Guiding Questions

AL **Why is one part of a polar molecule different from another?**	*One part of a polar molecule has a slightly positive charge and the other end has a slightly negative charge.*
OL **Why is water a polar compound?**	*The oxygen atom pulls more strongly on the shared valence electrons than the hydrogen atoms. Therefore, the oxygen end of the molecule has a partial negative charge. The hydrogen atoms are both on one side of the oxygen atom and together have a partial positive charge.*
BL **How do two polar molecules interact when they come into contact with each other?**	*The negative end of one molecule pulls on the positive end of the other, which causes the polar molecules to separate from one another.*

Word Origin

polar

Have students read the Latin origin of polar. Then ask the following question.

Ask: **How is a pole like a polar molecule?** *Both have opposite ends.*

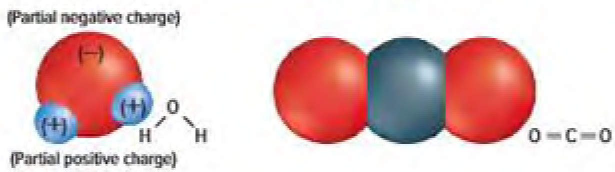
Nonpolar Molecules

Have students read the paragraphs and refer them to **Figure 9**. Some may be confused by the prefix *di-* in carbon dioxide. In **Figure 9**, students learn that the subscript 2 in CO_2 means there are two oxygen atoms in one molecule of carbon dioxide. Students will learn more about naming molecules and compounds later. Use the following questions to help students analyze the diagram and to assess their understanding of this concept.

Guiding Questions

AL **How is a water molecule different from a hydrogen molecule?**	*A water molecule is polar; a hydrogen molecule is nonpolar.*
OL **Why is a carbon dioxide molecule nonpolar?**	*The carbon and oxygen atoms share the valence electrons equally—neither atom pulls on the electrons more strongly than the other.*
BL **Compare the appearance of the water molecule to the appearance of the carbon dioxide.**	*In the water molecule, the atoms are different sizes and the oxygen atom is much bigger than the two hydrogen atoms. In the carbon dioxide molecule, all three atoms are about the same size.*

Visual Literacy: Molecule Drawings



Ask: Which balls represent hydrogen, oxygen, and carbon? *The two small, blue balls represent hydrogen; the grey balls represents carbon; the red balls hydrogen.*

Differentiated Instruction

AL **Two-Column Chart** Have students fill in a two-column chart like the one below that lists similarities and differences among single, double, and triple covalent bonds.

Single, Double and Triple Covalent Bonds	
Ways they are similar	They all contain atoms sharing valence electrons.
Ways they are different	In a single covalent bond, only one pair of valence electrons is shared; in a double bond, two pairs are shared; and in a triple bond, three pairs are shared.

BL **Illustrating Covalent Bonds** Have students create electron dot diagrams to show how the atoms in ammonia (NH_3) and water (H_2O) form single covalent bonds and how the atoms in oxygen (O_2) and quartz (SiO_2) form double covalent bonds. They should write a caption beneath each to explain what kind of covalent bond it shows.

Teacher Toolbox

Fun Fact

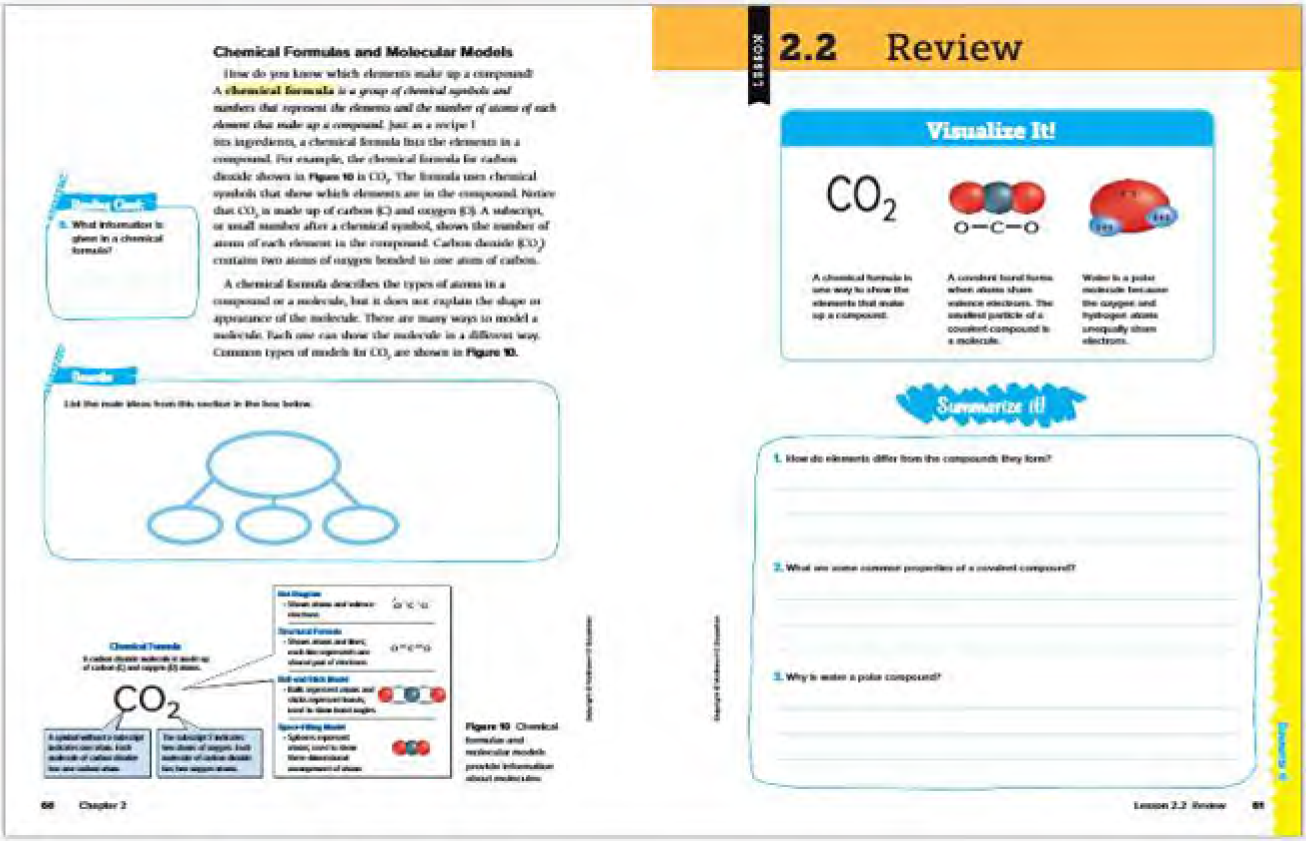
Melting and Boiling Points for Chlorine Two chlorine atoms combine and form a chlorine molecule. They are joined by a single covalent bond to make a substance with very low melting and boiling points. The melting point for chlorine is —34.6°C, and the boiling point is —100.98°C.

Real-World Science

A World Full of Hydrogen It is impossible to imagine our world without hydrogen. With only one proton and one electron, hydrogen is both the simplest and most plentiful element on Earth. Hydrogen makes up part of H_2O, or water, and is found in a number of different compounds, including ammonia (NH_3).

Reading Strategy

Compare and Contrast Have students reread the sections titled **Water and Other Polar Molecules** and **Nonpolar Molecules**. Ask them to complete a two-column chart that lists at least one similarity and one difference between polar and nonpolar molecules.



Chemical Formulas and Molecular Models

Discuss how a cooking recipe, such as the one to make cupcakes, is an example of a formula. For example, it shows how ingredients combine to produce something new. Remind students about the dictionary entry the class created for the word *formula*. Have students read the paragraphs. Then have them work together as a class to create a dictionary entry for the term *chemical formula* in students' own words. Use the following scaffolded questions to assess their understanding of this concept.

Guiding Questions

AL **How is a chemical formula like a recipe?**	*A chemical formula lists the elements that make up a compound much like a recipe lists the ingredients that make up a food.*
OL **What information is given in a chemical formula?**	*A chemical formula identifies the number and type of atoms present in a chemical compound.*
BL **What information is given in a chemical formula?**	*A chemical formula identifies the number and type of atoms present in a chemical compound.*

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Ask: To which Key Concept does each image relate?**

Summarize it!

The information needed to complete this graphic organizer can be found in the following sections:

- From Elements to Compounds
- Covalent Bonds—Electron Sharing

Teacher Toolbox

Teacher Demo

Oil and Water For this demonstration, you need a clear container, a cup of water, and a cup of dark-colored oil, such as olive oil.

1. **Pour the oil and water into the container and have students observe what happens.**
2. **Ask: You know that other polar compounds dissolve in water. Do you think oil is a polar compound?** *No.* **Why?** *Sample answer: It doesn't dissolve in water.*
3. Explain that the reason oil and water do not mix well is that oil is a nonpolar compound. When you pour them together, the opposite charges on the ends of the polar water molecules attract each other and pull away from the oil molecules.

Reading Strategy

Cause and Effect Have students reread the sections titled **Water and Other Polar Molecules** and **Nonpolar Molecules**. Then ask them to write one sentence to explain what causes a molecule to be polar and one sentence to explain what causes a molecule to be nonpolar.

Compounds, Chemical Formulas, and Covalent Bonds

Use Vocabulary

1. **Define** *covalent bond* in your own words.

2. The group of symbols and numbers that shows the types and numbers of atoms that make up a compound is a

3. **Use the term** *molecule* in a complete sentence.

Understand Key Concepts

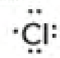
4. **Contrast** Name at least one way water (H_2O) is different from the elements that make up water.

5. **Explain** why water is a polar molecule.

6. A sulfur dioxide molecule has one sulfur atom and two oxygen atoms. Which is its correct chemical formula?
   A. SO_2
   B. $(SO)_2$
   C. S_2O_2
   D. S_2O

Interpret Graphics

7. **Examine** the electron dot diagram for chlorine below.



In chlorine gas, two chlorine atoms join to form a Cl_2 molecule. How many pairs of valence electrons do the atoms share?

8. **Compare and Contrast** Copy and fill in the graphic organizer below to identify at least one way polar and nonpolar molecules are similar and one way they are different.

Polar and Nonpolar Molecules	
Similarities	
Differences	

Critical Thinking

9. **Develop** an analogy to explain the unequal sharing of valence electrons in a water molecule.

My Notes

Use Vocabulary

1. Possible answer: A covalent bond forms when two or more atoms share electrons.
2. chemical formula
3. Possible answer: A water molecule is made up of two hydrogen atoms and one oxygen atom.

Understand Key Concepts

4. Possible answer: Water is a liquid at room temperature, but hydrogen and oxygen are gases.
5. The oxygen atom is on one side of the water molecule and pulls on the valence electrons more strongly than the two hydrogen atoms at the other end of the molecule. Therefore, the oxygen end has a partial negative charge, while the hydrogen end has a partial positive charge.
6. A SO_2

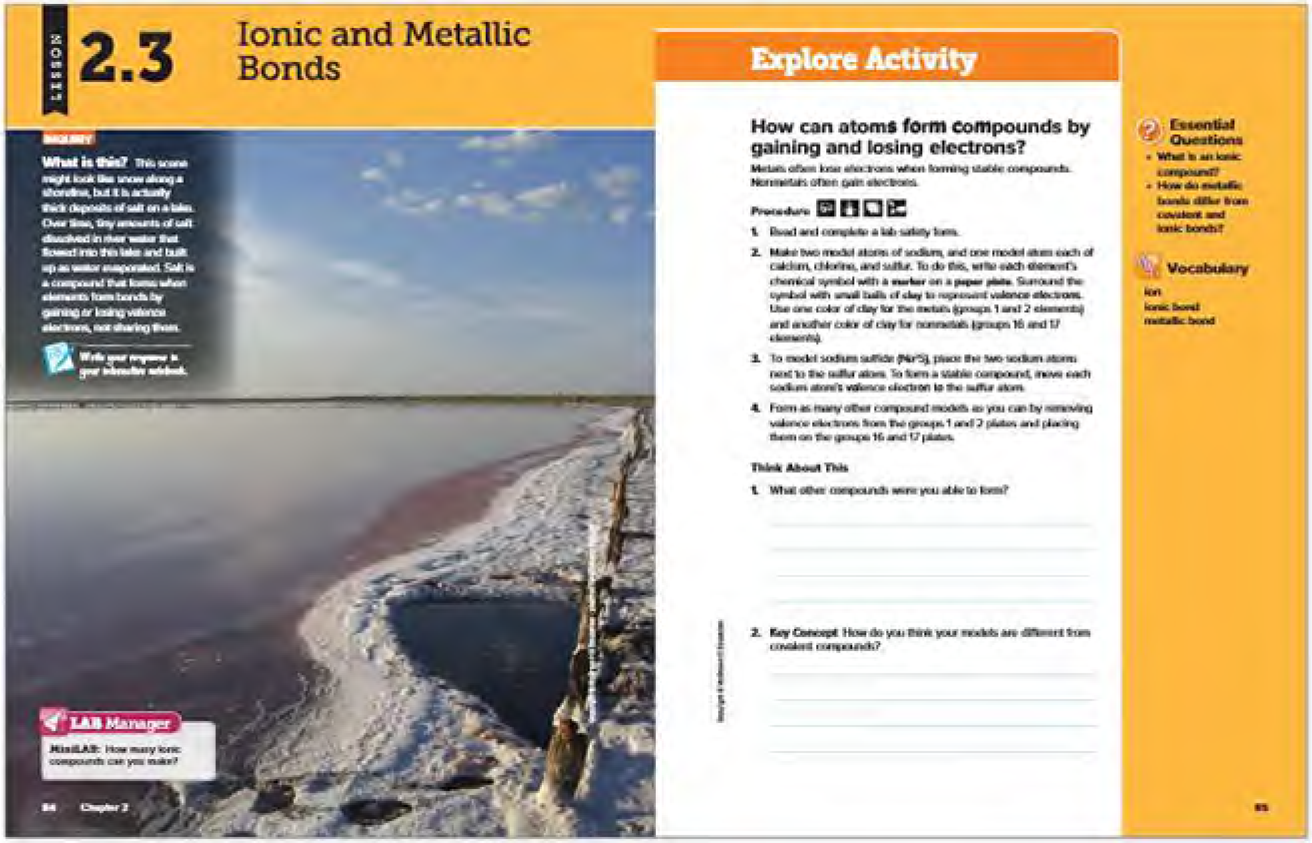
Interpret Graphics

7. 1 pair of electrons
8. Similarities: Both contain covalent bonds. Differences: Polar molecules have a slight charge at each end, while nonpolar molecules do not.

Critical Thinking

9. The analogy should demonstrate the slightly stronger pull that oxygen has on the electrons than the hydrogen atoms have.

Teacher Notes



INQUIRY

About the Photo **What is this?** Explain to students that when salty water washes onto a shore and then rolls away, it can leave some salt behind. The salt builds up over time and can form deposits on the beach like those shown in the photo.

Guiding Questions

AL **Look at the salt in this photo. If you poured salt into a glass of water, would it dissolve?**	*Yes; salt dissolves in water.*
OL **Do you think salt attracts water molecules or pushes them away? Why?**	*Salt probably attracts water molecules because they dissolve in water.*
BL **Knowing that salt dissolves in water, do you think salt is more likely to be polar or nonpolar? Explain your answer.**	*Salt is more likely to be polar because it dissolves in water by attracting polar water molecules.*

LAB Manager

Labs can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Key Concepts and be able to answer these questions. Have students write each question in their Science Journals. Revisit each question as you cover its relevant content.

Vocabulary

Create Classroom Flash Cards

1. Have students work in pairs to create one flash card for each vocabulary term in this lesson.
2. At the beginning of the lesson, have them locate the three vocabulary terms on the lesson opener page. Then ask them to write each term on the front of an index card.
3. As they complete the lesson, student partners should work together to write a definition for each vocabulary term in their own words on the back of their index cards.
4. At the end of the lesson, ask the students to share their flash cards with another pair.

Explore Activity

How can atoms form compounds by gaining and losing electrons?

Prep: 5 *min* **Class:** 15 *min*

Purpose
To form ionic compounds by manipulating model atoms

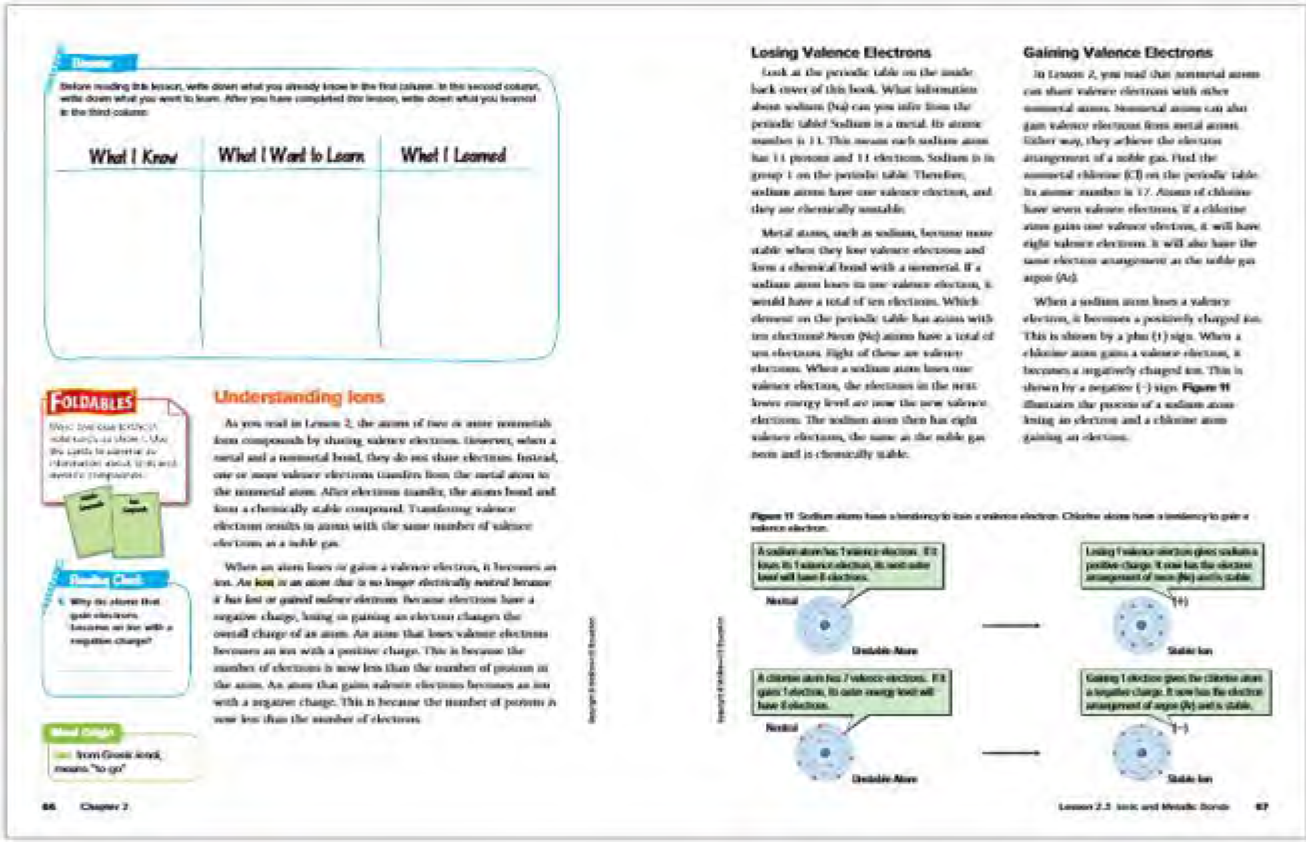
Materials
four paper plates, two colors of modeling clay, marker

Before You Begin
Each student will need four equal-sized balls of one color of clay to represent the metals and 13 of another color to represent the nonmetals.

Think About This

1. Students should be able to form NaCl, $CaCl_2$, and CaS.
2. **Key Concept** In covalent bonds, the electrons are shared. In this activity, the electrons are transferred from one atom to another.

Teacher Notes



What I Know | What I Want to Learn | What I Learned

FOLDABLES

Understanding Ions

Losing Valence Electrons

Gaining Valence Electrons

66 Chapter 2

Lesson 2.3 Ionic and Metallic Bonds 67

Understanding Ions

Remind students that in a covalent bond, atoms share valence electrons. Ask them to discuss their experiences with the **Launch Lab** and talk about how they moved electrons from one atom to another to create compounds. Explain that when valence electrons move from one atom to another, a bond forms that is different from when atoms share electrons. After students read the paragraphs, ask the following scaffolded questions. Then use the vocabulary exercise.

Guiding Questions

AL **What is an ion?**	*It is an atom that has a charge because it has gained or lost valence electrons.*
OL **Why do atoms that gain electrons become an ion with a negative charge?**	*Electrons have negative charges. When an atom gains valence electrons, it has more electrons than protons and becomes negatively charged.*

Word Origin

ion

Explain that the word *ion* comes from a Greek word that means "to go." Tell students that an ion is an atom with a charge because one or more valence electrons have gone to another atom or come from another atom.

Ask: How do you think the scientific definition of the word ion relates to the Greek origin of the word? *Ions form when valence electrons "go" from one atom to another.*

Losing Valence Electrons

Remind students about the photo of the racing team from **Lesson 1**. The team had four pairs of oars, for a total of eight, which kept the boat stable. Atoms with a similar configuration of valence electrons are stable. Atoms with fewer than eight valence electrons are unstable. Have students turn to the periodic table on the inside back cover of the text. Ask them to locate sodium (Na) and find its group number (1) and atomic number (11). Then have students read the paragraphs and review **Figure 4** from **Lesson 1** and **Figure 11**. Ask the following scaffolded questions to assess their comprehension of this concept.

Guiding Questions

AL **How can metal atoms become stable?**	*They can bond with nonmetal atoms and lose valence electrons.*
OL **Would losing a valence electron make a sodium atom an ion? Why or why not?**	*Yes; sodium lost a valence electron and now has more protons than electrons.*
BL **Sodium (Na) and neon (Ne) atoms have almost the same number of electrons. Why is a neon atom stable while a sodium atom is unstable?**	*A neon atom has four pairs of valence electrons, which makes it stable. A sodium atom has just one valence electron, which makes it unstable.*

Gaining Valence Electrons

Remind students that electrons have a negative charge, and when an atom gains or loses a valence electron, it is no longer electrically neutral. Have students turn to the periodic table on the inside back cover of the text. Ask them to locate chlorine (Cl) on the table and find its group number (17) and atomic number (17). Then refer students to the diagrams in **Figure 11** and have them read the paragraphs. Ask the following scaffolded questions to assess their understanding.

Guiding Questions

OL **Chlorine and argon have almost the same number of electrons. Why is an argon atom stable while a chlorine atom is unstable?**	*An argon atom has four pairs of valence electrons, which makes it stable. A chlorine atom has seven valence electrons, one of which is not paired, which makes it unstable.*
OL **Are atoms of a group 16 element more likely to gain or lose valence electrons?**	*They are more likely to gain valence electrons and become stable.*
BL **What happens to a sodium atom and a chlorine atom when they combine?**	*The sodium atom loses a valence electron to chlorine. The sodium atom becomes a positively charged ion, and the chlorine atom becomes a negatively charged ion.*

Differentiated Instruction

AL **Web Site on Ions** Have students find a partner and share what they have learned about how atoms gain or lose valence electrons and become ions. Each pair of students should work together to draw an illustration for a Web page on ions. They should include a diagram, a definition of ions, and the name of a link that a user could click to find more information.

BL **The Adventures of an Ion** Have students work in pairs or small teams to create a comic strip or a short comic book about a sodium atom. The comic strip should describe what happens when a metal atom interacts with a nonmetal atom and forms an ion.

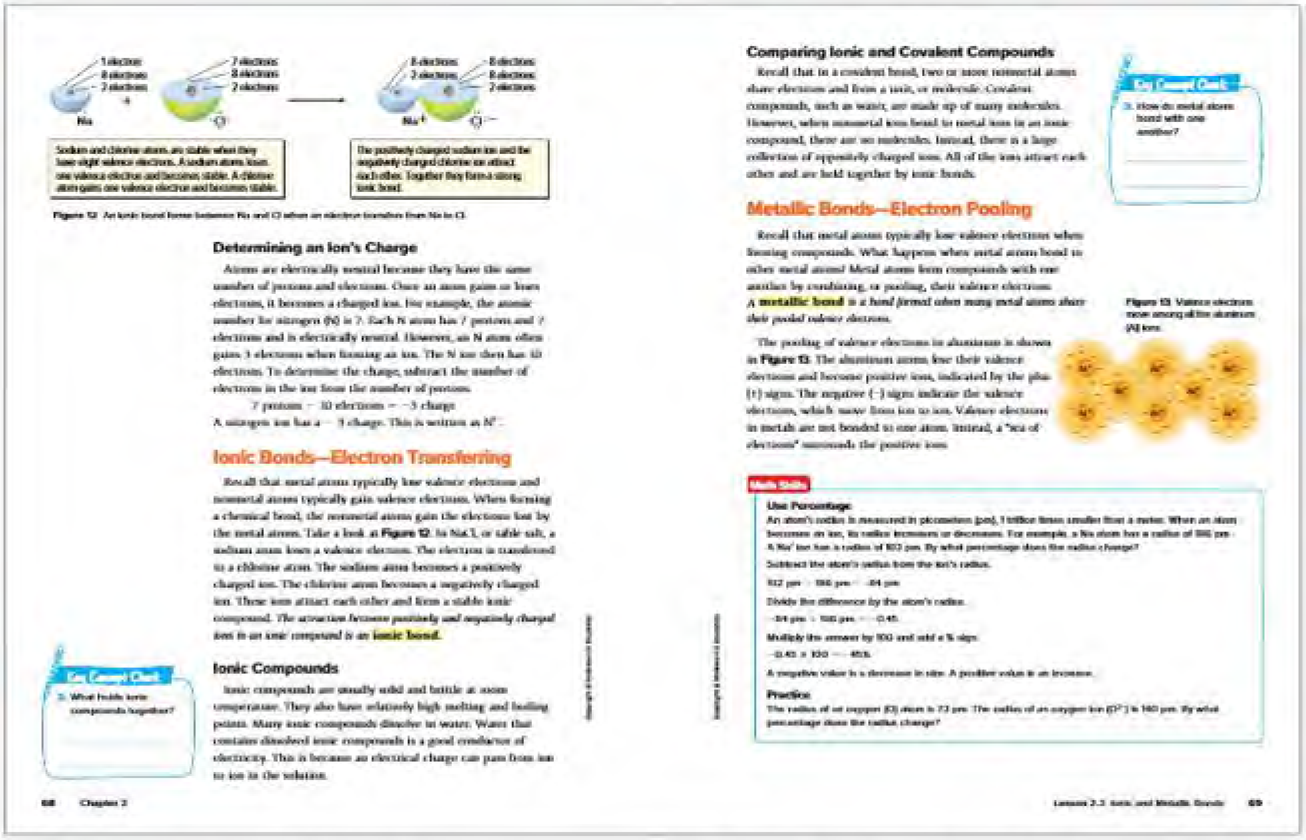
Teacher Toolbox

Careers in Science

Astronauts The Sun gives off radiation in the form of solar storms packed with heavy ions. These are very energetic ions that can damage human tissue and lead to health problems. On Earth, the atmosphere protects us from heavy ions. But astronauts who travel to the Moon no longer have that protection. Scientists are working on ways to forecast solar storms, giving astronauts enough time to seek shelter. The key is studying the electrons present in the Sun's radiation. They can be detected before a solar storm arrives so astronauts can be alerted that dangerous weather is on the way.

Cultural Diversity

The Value of Salt As the ions in salt dissolve on your tongue, it creates a flavorful sensation. Because of the flavor it adds to food, salt has been a valuable commodity since ancient times. In some cultures, it was so precious that it was traded for gold. Ancient Chinese coins were made of salt. Cakes made of salt were also used as money in the Mediterranean region.



Determining an Ion's Charge

Have students read the paragraph. Direct them to the periodic table. Nitrogen is a nonmetal with five valence electrons. When forming an ionic bond, nonmetal atoms gain electrons and acquire the same electron arrangement as the nearest noble gas. For nitrogen, the nearest noble gas is neon with an atomic number of ten. Therefore, nitrogen gains three electrons. Then ask students these scaffolded questions.

Guiding Questions

AL **A fluorine ion has one extra electron. What is its charge?**	*−1 (negative one)*
OL **Find calcium (Ca) and selenium (Se) on the periodic table. How does the charge of a calcium ion and a selenium ion compare?**	*A calcium ion has a +2 charge, and a selenium ion has a −2 charge.*

Have students read the paragraph and refer them to **Figure 12.** After they read, use the following questions to assess their comprehension.

Ask: What holds ionic compounds together? *The attraction of oppositely charged ions holds ionic compounds together.*

Ionic Bonds—Electron Transferring

Have students read the paragraph. Remind them that ionic bonds involve the transfer of electron(s) from a metal atom to a nonmetal atom. The attraction between positive and negative ions creates the ionic bond.

Ionic Compounds

Have students read the paragraphs and use the following scaffolded questions to assess their comprehension.

Guiding Questions

OL **Is carbon dioxide an ionic compound? Why or why not?**	*No; when carbon and oxygen bond, they share valence electrons and do not form ions.*
AL **Find calcium (Ca) and selenium (Se) on the periodic table. How does the charge of a calcium ion and a selenium ion compare?**	*Possible answers: usually solid; brittle at room temperature; relatively high melting and boiling points; good conductors of electricity*

Math Skills

Use Percentage

Have students read the Math Skills box and answer the Practice question.

140 pm − 73 pm = 67 pm

$\frac{67\ pm}{73\ pm} = 0.91$

0.91 × 100 = 91%

Comparing Ionic and Covalent Compounds

Remind students that covalent compounds such as water and sugar have low melting and boiling points and are poor conductors of electricity.

Metallic Bonds—Electron Pooling

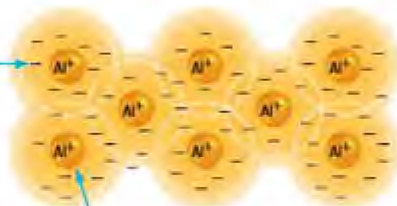
Discuss what it means to "pool" things. Have students read the paragraphs and study Figure 13.

Ask: **How do metal atoms bond with one another?** *A metallic bond forms when metal atoms pool their valence electrons. The valence electrons move freely among the metal atoms.*

Visual Literacy: Valance Electrons

Help students learn how metal atoms pool valence electrons. Refer to **Figure 13.**

Ask: **What represents valence electrons in this diagram?** *The minus signs represent valence electrons*



Ask: **What represents aluminum ions?** *The smaller, darker circles with plus signs represent aluminum ions.*

Differentiated Instruction

AL **Venn Diagram** Have students fill in a Venn diagram to compare ionic bonds to metallic bonds. Their diagrams should list one unique detail for each type of bond and one detail the two types have in common.

BL **Electron Equations** Have students use the periodic table in their textbooks to determine how many electrons potassium (K) and calcium (Ca) must lose to become stable and how many electrons phosphorus (P) and selenium (Se) must gain. Ask them to write the symbol for each ion formed and to create an equation that demonstrates the difference between protons and electrons in each.

Teacher Toolbox

Fun Fact

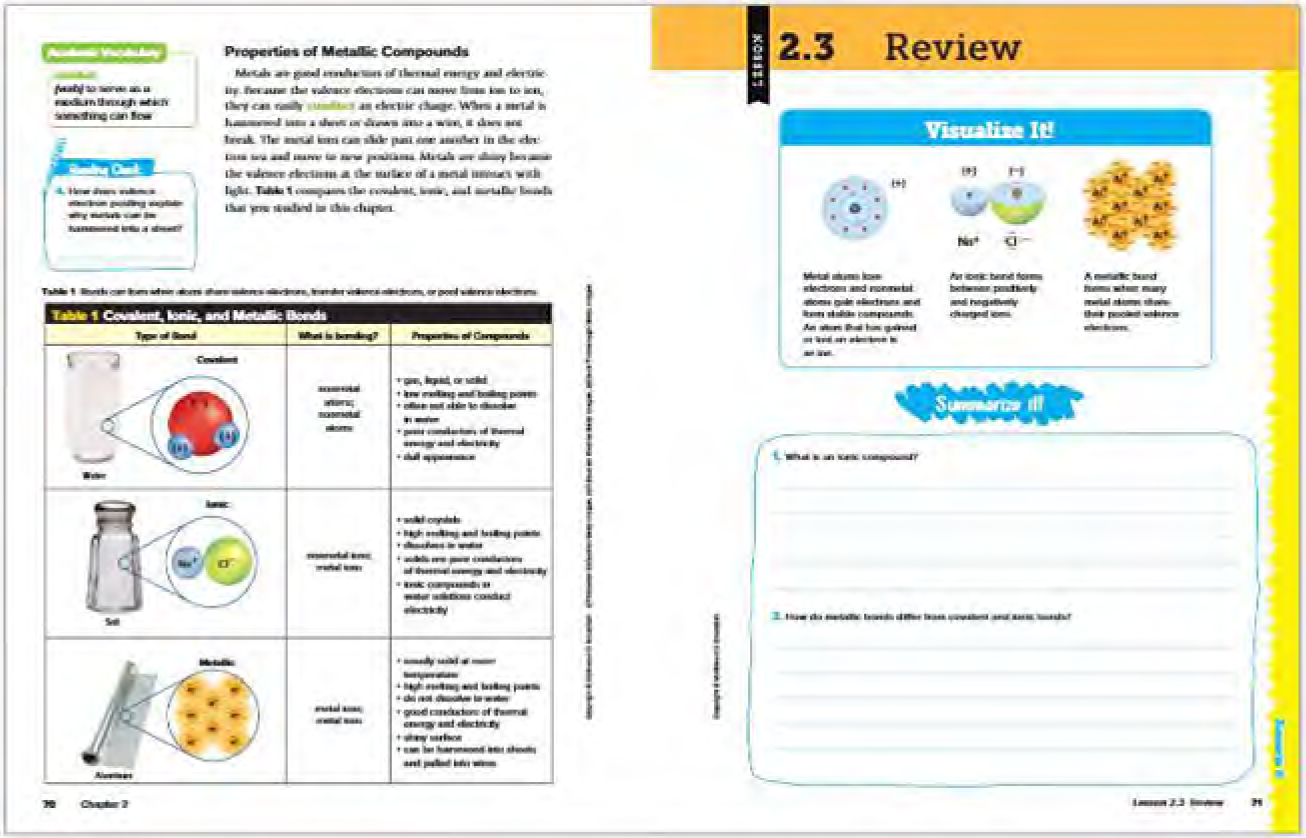
Melting and Boiling Points for Magnesium Oxide When magnesium and oxygen combine, they form a white powder called magnesium oxide (MgO_2) that is used in cement, cosmetics, and medicine. As a result of its ionic bond, this compound has extremely high melting and boiling points. The melting point is 2,800°C and the boiling point is 3,582°C!

Real-World Science

Neon Signs Because noble gases are stable, it is nearly impossible for their atoms to gain or lose electrons. Scientists, however, have found a way to stimulate gases so they can transfer a charge from one atom to another. When an electric current passes through a tube filled with neon gas, the electrons become excited and transfer the electricity. They also give off a very bright light. In fact, it is so bright that it can light up an entire sign, which is how neon signs work.

Reading Strategy

Compare and Contrast Have students write a short paragraph to compare and contrast covalent bonds, ionic bonds, and metallic bonds. They should briefly explain one way these three types of bonds are the same and one way they are different.



Properties of Metallic Compounds

Bring a sheet of aluminum foil to class and hold it up for students to observe. Ask them to describe some of its properties. Remind them that one property of metal is its ability to be hammered into sheets. Then have students read the paragraph and refer to **Table 1.**

Guiding Questions

AL **Why are metallic compounds good conductors of electricity?**	*Because valence electrons can move around, an electrical charge can pass from ion to ion in an ionic compound.*
OL **How does valence electron pooling explain why metals can be hammered into a sheet?**	*When a metal is hammered into a sheet, it does not break. The valence electrons slide past each other in the sea of electrons and move to new positions.*

ACADEMIC VOCABULARY

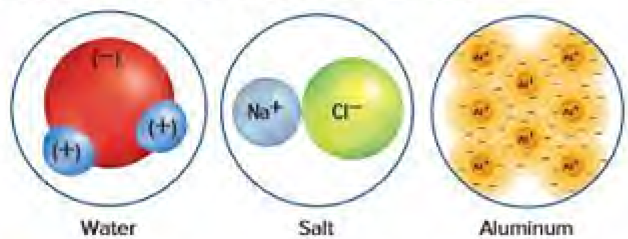
conduct

Have students look up the term conduct in a dictionary and discuss everyday definitions of the word.

Ask: **How does knowing other definitions of the word conduct help you understand the scientific definition?** *Answers may vary. Possible answer: When a guide conducts tourists through a museum, he or she helps them move through the museum. That is analogous to the way that metal helps electricity move along a wire.*

Visual Literacy: Covalent, Ionic, and Metallic Bonds

Refer students to **Table 1**. Use the following questions to help them analyze the diagram and assess their understanding.



Ask: **Which compound conducts electricity in water solutions?** ionic compounds **Consider the physical properties of that compound in its solid state. How might that explain why it does not conduct electricity as a solid?** *The ions in a solid are not free to move because they are involved in ionic bonding. However when salt mixes with water, the ionic bonds break and ions are suspended in the water. It is these ions that conduct electricity.*

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. Ask: **Which Key Concept does each image relate to?**

Summarize it!

The information needed to complete this graphic organizer can be found in the following sections:

- Sound Waves and Matter
- Understanding Ions
- Ionic Bonds—Electron Transferring
- Metallic Bonds—Electron Pooling
- Properties of Metallic Compounds

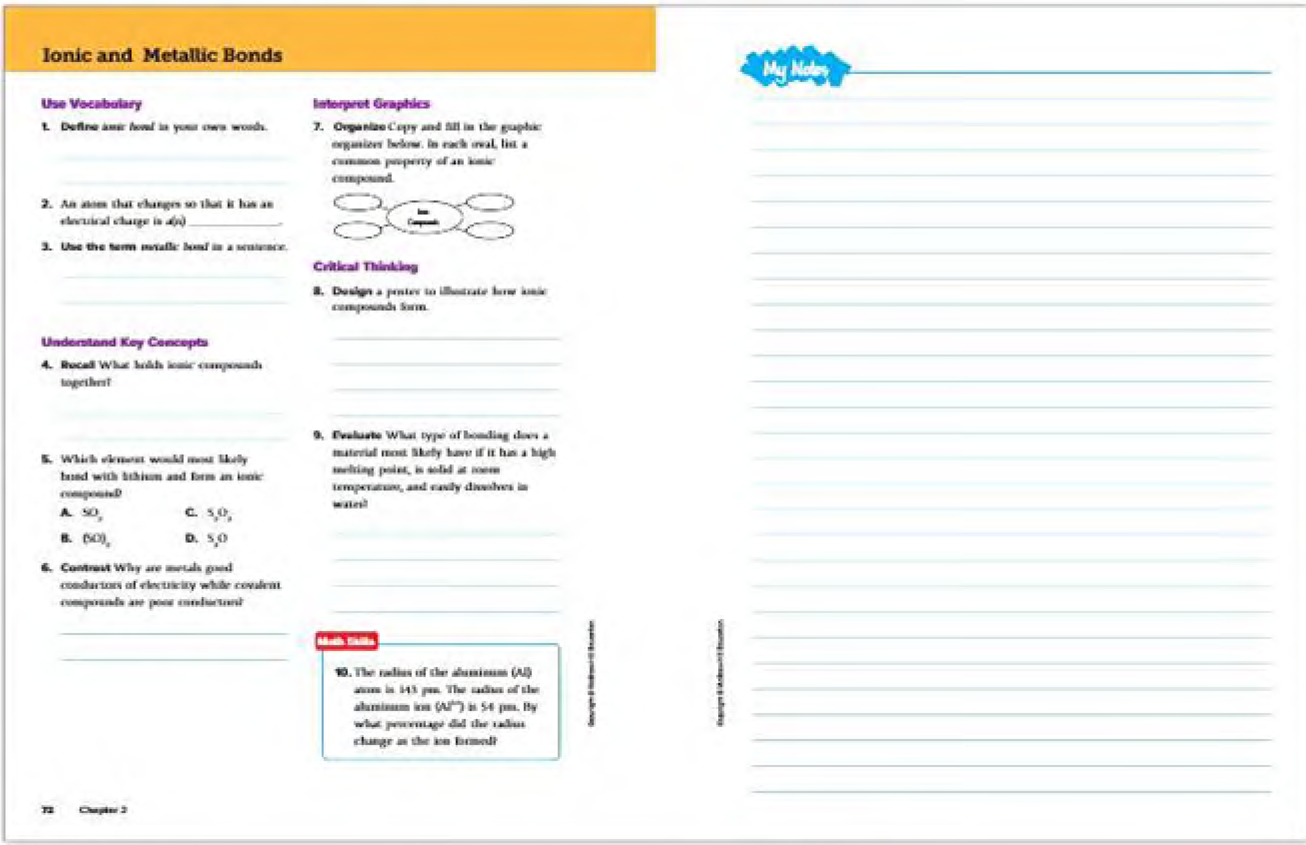
Teacher Toolbox

Real-World Science

Shiny Metals Because metallic compounds reflect light and are shiny, they are very pleasing to the eye. As a result, they are often used to make earrings, bracelets, and other kinds of jewelry. They are also used to make picture frames, mirrors, and many other things with shiny surfaces. Aluminum and silver are the shiniest metals, followed by gold.

Reading Strategy

Summarize Have students reread the section titled **Properties of Metallic Compounds**. Ask them to write a short summary to describe a metallic compound and its major properties. Remind them that summaries primarily include the main ideas of a topic and few supporting details.



Ionic and Metallic Bonds

Use Vocabulary

1. **Define** *ionic bond* in your own words.
2. An atom that changes so that it has an electrical charge is a(n) ______.
3. **Use the term** *metallic bond* in a sentence.

Understand Key Concepts

4. **Recall** What holds ionic compounds together?
5. Which element would most likely bond with lithium and form an ionic compound?
   - A. SO_2
   - B. $(SO)_2$
   - C. S_2O_2
   - D. S_2O
6. **Contrast** Why are metals good conductors of electricity while covalent compounds are poor conductors?

Interpret Graphics

7. **Organize** Copy and fill in the graphic organizer below. In each oval, list a common property of an ionic compound.

Critical Thinking

8. **Design** a poster to illustrate how ionic compounds form.
9. **Evaluate** What type of bonding does a material most likely have if it has a high melting point, is solid at room temperature, and easily dissolves in water?

Math Skills

10. The radius of the aluminum (Al) atom is 143 pm. The radius of the aluminum ion (Al^{3+}) is 54 pm. By what percentage did the radius change as the ion formed?

72 Chapter 2

My Notes

Use Vocabulary

1. Possible answer: An ionic bond is the attraction between positive ions and negative ions.
2. ion
3. Possible answer: A metallic bond forms when valence electrons are free to move around positive metal ions.

Understand Key Concepts

4. The attraction between a positive ion and a negative ion holds an ionic bond together.
5. C. fluorine 1
6. The electrical charge is easily carried from atom to atom by freely moving valence electrons of metals. Valence electrons are not free to move in covalent bonds.

Interpret Graphics

7. Possible answers: solid crystals, high melting point, high boiling point, poor conductors of thermal energy, and electricity

Critical Thinking

8. Posters should illustrate the formation of positive ions by losing electrons and the formation of negative ions by gaining electrons.
9. ionic bonding

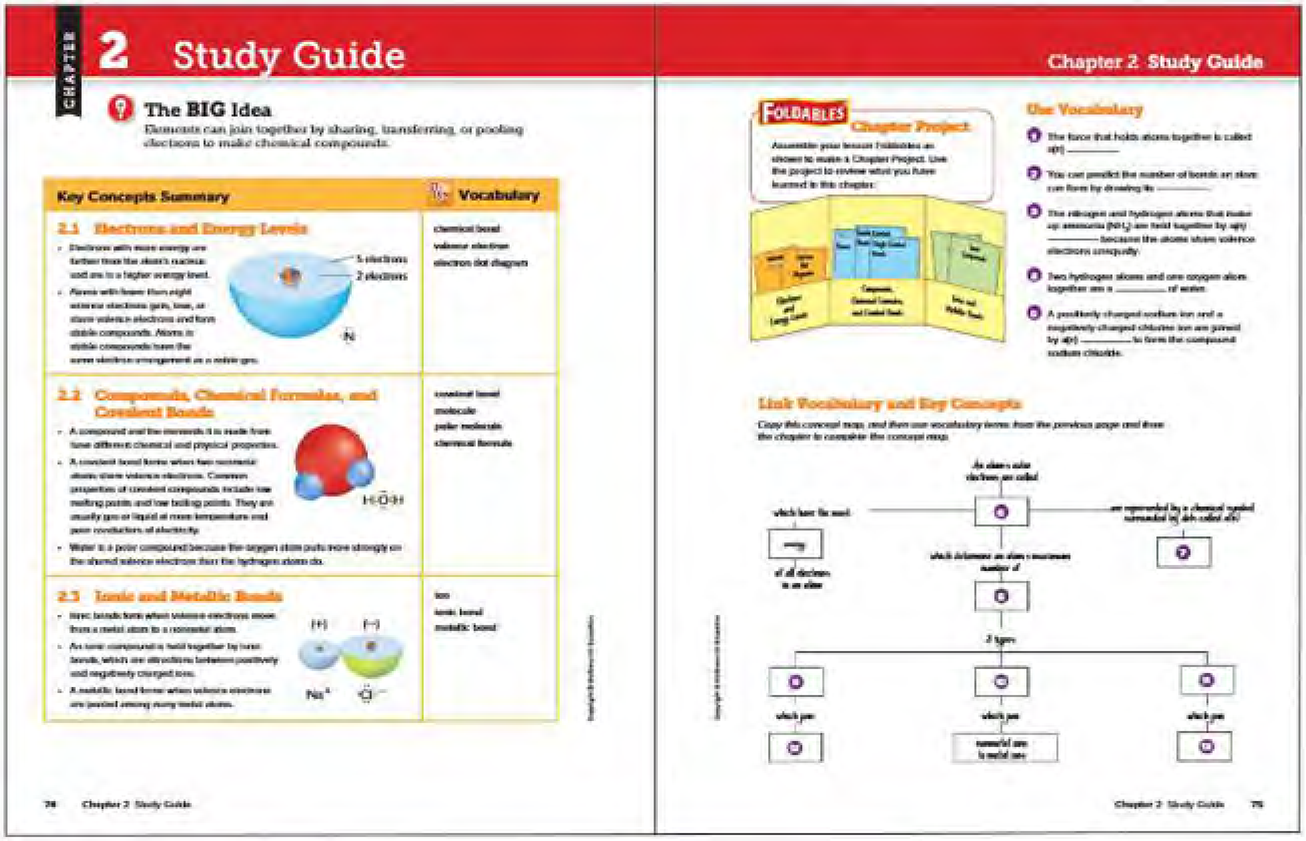
Math Skills

10. 54 pm − 143 pm = −89 pm

    −89 pm − 143 pm = −0.62

    −0.62 × 100 = −62%

Teacher Notes



Key Concepts Summary

Study Strategy: Check Answers to Key Concept Questions

Teach students to focus on the areas in which they lack understanding and to spend less time on concepts they have mastered.

1. Write the Key Concept questions from the start of each lesson on chart paper or the board.
2. Ask students to answer each question in their Science Journals.
3. Instruct students to make note of the questions they had a difficult time answering. Then have them compare their answers to the Key Concepts Summary in the Chapter Study Guide. Tell them to write a check beside any answers that were correct and to circle any answers that were inaccurate or incomplete.
4. Have students look back through the chapter to locate any information relevant to the answers they circled. Have them use this information to rewrite their answers.

Example:

Atoms gain, lose, or share electrons to become stable. √

An ionic compound is a substance that forms when atoms share electrons.

In a metallic bond, atoms pool their valence electrons. √

Vocabulary

Study Strategy: In Your Own Words

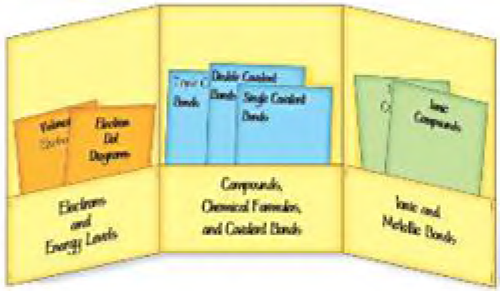
Ask students to create vocabulary definitions using their own words. Connecting vocabulary words to students' own language promotes understanding more effectively than pure memorization.

1. Have students create a two-column table like the one below in their Science Journals.
2. Have them write the vocabulary words in the Study Guide in the left column.
3. Ask students to describe what they know about the chapter's vocabulary words using their own words (without referring to the textbook).

Example:

Vocabulary Word	My Definition
Valence Electron	an electron that moves around the outer edge of an atom and is free to interact with other atoms

FOLDABLES® Chapter Project



Use the Foldables® Chapter Project as a way to connect Key Concepts

1. Ask students to organize their Foldables® in a way that reflects how the concepts in each Foldable relate to each other.
2. Use glue or staples to hold the sheets together as needed.
3. When complete, ask students to place their Foldables® Chapter Project at the front of the room. Have the class critique and discuss the way in which students have organized their Foldables®.

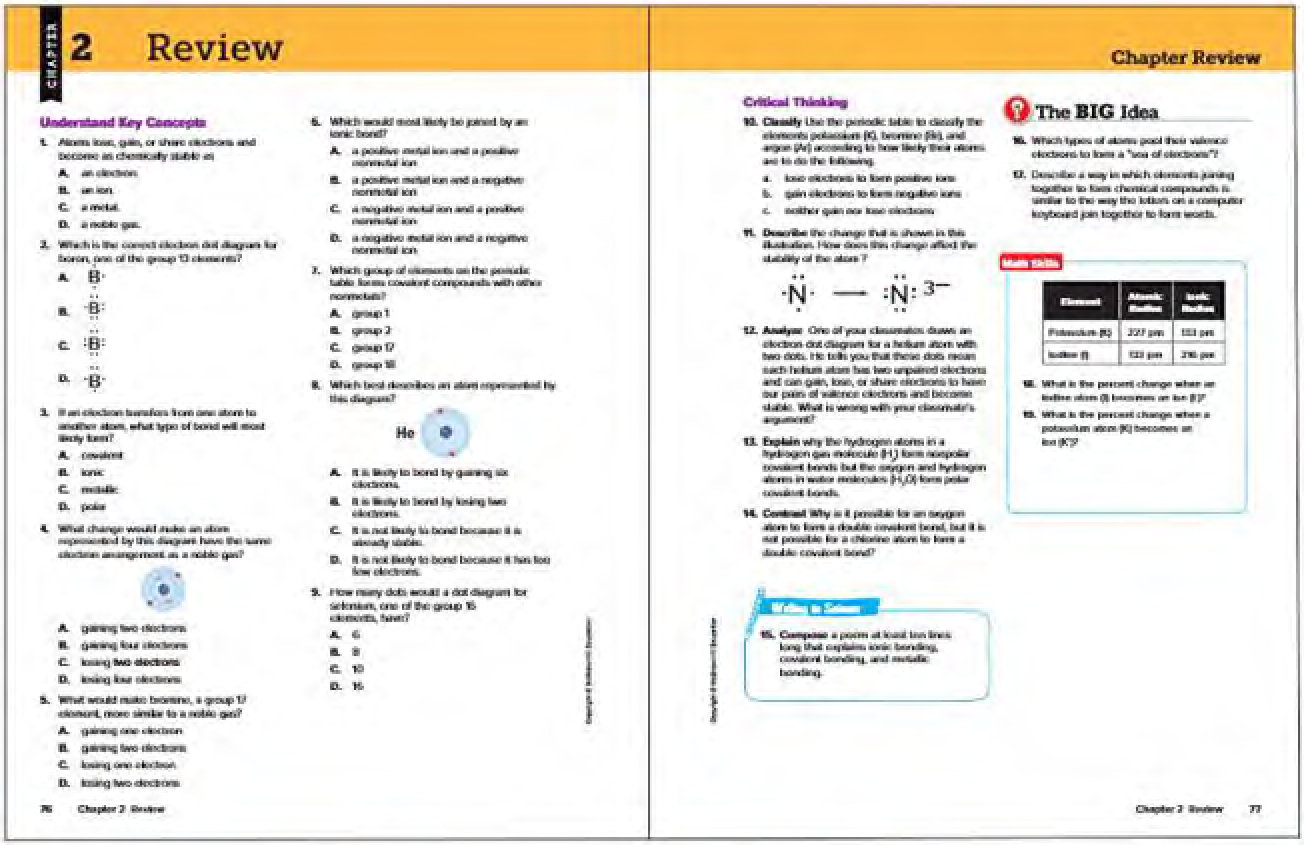
Use Vocabulary

1. chemical bond
2. electron dot diagram
3. covalent bond
4. molecule
5. ionic bond

Link Vocabulary and Key Concepts

6. valence electrons
7. electron dot diagram
8. bonds
9. covalent bonds
10. ionic bonds
11. metallic bonds
12. nonmetal atoms to nonmetal atoms
13. metal atoms to metal atoms

Teacher Notes



CHAPTER 2 Review

Understand Key Concepts

1. Atoms lose, gain, or share electrons and become as chemically stable as
   - A. an electron.
   - B. an ion.
   - C. a metal.
   - D. a noble gas.
2. Which is the correct electron dot diagram for boron, one of the group 13 elements?
   - A. ·B· (three dots)
   - B. :B: (five dots)
   - C. :B: (seven dots)
   - D. ·B· (five dots)
3. If an electron transfers from one atom to another atom, what type of bond will most likely form?
   - A. covalent
   - B. ionic
   - C. metallic
   - D. polar
4. What change would make an atom represented by this diagram have the same electron arrangement as a noble gas?
   - A. gaining two electrons
   - B. gaining four electrons
   - C. losing two electrons
   - D. losing four electrons
5. What would make bromine, a group 17 element, more similar to a noble gas?
   - A. gaining one electron
   - B. gaining two electrons
   - C. losing one electron
   - D. losing two electrons
6. Which would most likely be joined by an ionic bond?
   - A. a positive metal ion and a positive nonmetal ion
   - B. a positive metal ion and a negative nonmetal ion
   - C. a negative metal ion and a positive nonmetal ion
   - D. a negative metal ion and a negative nonmetal ion
7. Which group of elements on the periodic table forms covalent compounds with other nonmetals?
   - A. group 1
   - B. group 2
   - C. group 17
   - D. group 18
8. Which best describes an atom represented by this diagram?

   He

   - A. It is likely to bond by gaining six electrons.
   - B. It is likely to bond by losing two electrons.
   - C. It is not likely to bond because it is already stable.
   - D. It is not likely to bond because it has too few electrons.
9. How many dots would a dot diagram for selenium, one of the group 16 elements, have?
   - A. 6
   - B. 8
   - C. 10
   - D. 16

76 Chapter 2 Review

Chapter Review

Critical Thinking

10. **Classify** Use the periodic table to classify the elements potassium (K), bromine (Br), and argon (Ar) according to how likely their atoms are to do the following.
    - a. lose electrons to form positive ions
    - b. gain electrons to form negative ions
    - c. neither gain nor lose electrons
11. **Describe** the change that is shown in this illustration. How does this change affect the stability of the atom?

    $\cdot\ddot{N}\cdot \longrightarrow :\ddot{N}:^{3-}$

12. **Analyze** One of your classmates draws an electron dot diagram for a helium atom with two dots. He tells you that these dots mean each helium atom has two unpaired electrons and can gain, lose, or share electrons to have four pairs of valence electrons and become stable. What is wrong with your classmate's argument?
13. **Explain** why the hydrogen atoms in a hydrogen gas molecule (H_2) form nonpolar covalent bonds but the oxygen and hydrogen atoms in water molecules (H_2O) form polar covalent bonds.
14. **Contrast** Why is it possible for an oxygen atom to form a double covalent bond, but it is not possible for a chlorine atom to form a double covalent bond?

Writing in Science

15. **Compose** a poem at least ten lines long that explains ionic bonding, covalent bonding, and metallic bonding.

The BIG Idea

16. Which types of atoms pool their valence electrons to form a "sea of electrons"?
17. Describe a way in which elements joining together to form chemical compounds is similar to the way the letters on a computer keyboard join together to form words.

Math Skills

Element	Atomic Radius	Ionic Radius
Potassium (K)	227 pm	133 pm
Iodine (I)	133 pm	216 pm

18. What is the percent change when an iodine atom (I) becomes an ion (I^-)?
19. What is the percent change when a potassium atom (K) becomes an ion (K^+)?

Chapter 2 Review 77

Understand Key Concepts

1 **D.** a noble gas.

2 **A.**

3 **B.** ionic

4 **C.** losing two electrons

5 **A.** gaining one electron

6 **B.** a positive metal ion and a negative nonmetal ion

7 **C.** group 17

8 **C.** It is not likely to bond because it is already stable.

9 **A.** 6

Critical Thinking

10 Potassium (K) is likely to lose electrons to form positive ions. Bromine is likely to gain electrons to form negative ions. Argon is neither likely to gain nor lose electrons.

11 A nitrogen atom has gained three electrons to form an ion with a −3 charge. This has made the nitrogen ion more stable.

12 Helium has only two electrons, but the lowest energy level can only hold two electrons, which are paired. As a result, helium is stable without gaining, losing, or sharing electrons.

13 Each hydrogen atom in a gas molecule (H_2) has an equal pull on the electrons, and the molecule is nonpolar. In contrast, the oxygen atom in a water molecule has a greater pull on electrons than the two hydrogen atoms. Therefore, electrons are shared unequally and the molecule is polar.

14. Oxygen atoms have six valence electrons. They are chemically stable with eight valence electrons, similar to a noble gas. Oxygen can form two single bonds or one double bond. Chlorine atoms have seven valence electrons and are stable with eight valence electrons, similar to a noble gas. Each chlorine atom can form one single bond with another atom.

Writing in Science

15 Poems should explain that atoms gain or lose electrons to form ionic bonds, atoms share electrons to form covalent bonds, and metals pool their electrons to form metallic bonds.

The BIG Idea

16 metals

17 Elements combine and form new substances, just as letters combine and form new words.

Math Skills

18 216 pm – 133 pm = 83 pm

$$\frac{83\text{ pm}}{133\text{ pm}} = 0.62$$

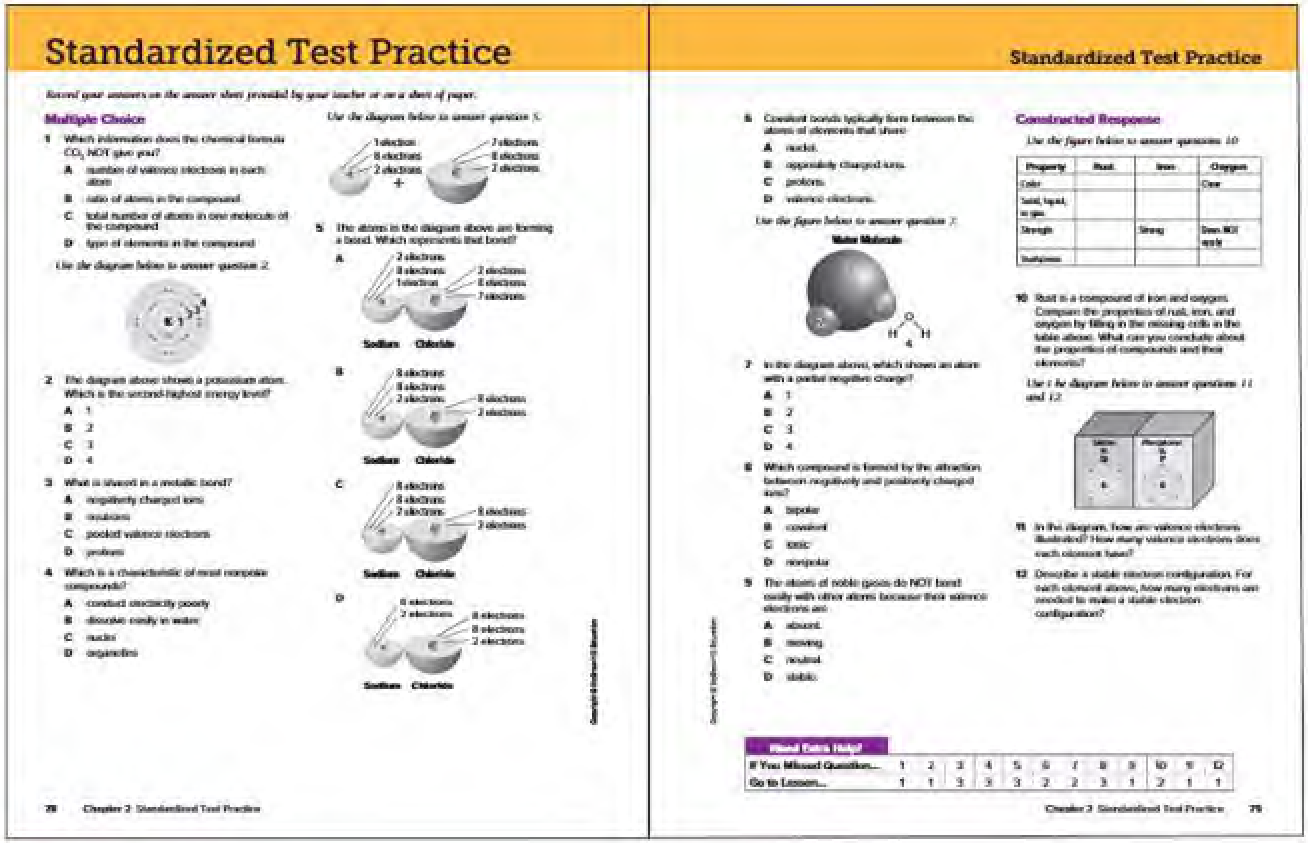
0.62 × 100 = 62%

19 133 pm – 227 pm = –94 pm

$$\frac{-94\text{ pm}}{227\text{ pm}} = -41$$

–0.41 × 100 = –41%

Teacher Notes



Standardized Test Practice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

Multiple Choice

1 Which information does the chemical formula CO_2 NOT give you?
- A number of valence electrons in each atom
- B ratio of atoms in the compound
- C total number of atoms in one molecule of the compound
- D type of elements in the compound

Use the diagram below to answer question 2.

2 The diagram above shows a potassium atom. Which is the second-highest energy level?
- A 1
- B 2
- C 3
- D 4

3 What is shared in a metallic bond?
- A negatively charged ions
- B neutrons
- C pooled valence electrons
- D protons

4 Which is a characteristic of most nonpolar compounds?
- A conduct electricity poorly
- B dissolve easily in water
- C nuclei
- D organelles

Use the diagram below to answer question 5.

5 The atoms in the diagram above are forming a bond. Which represents that bond?

Sodium Chloride

6 Covalent bonds typically form between the atoms of elements that share
- A nuclei.
- B oppositely charged ions.
- C protons.
- D valence electrons.

Use the figure below to answer question 7.

Water Molecule

7 In the diagram above, which shows an atom with a partial negative charge?
- A 1
- B 2
- C 3
- D 4

8 Which compound is formed by the attraction between negatively and positively charged ions?
- A bipolar
- B covalent
- C ionic
- D nonpolar

9 The atoms of noble gases do NOT bond easily with other atoms because their valence electrons are
- A absent.
- B moving.
- C neutral.
- D stable.

Constructed Response

Use the figure below to answer question 10.

Property	Rust	Iron	Oxygen
Color			Clear
Solid, liquid, or gas			
Strength		Strong	Does NOT apply
Usefulness			

10 Rust is a compound of iron and oxygen. Compare the properties of rust, iron, and oxygen by filling in the missing cells in the table above. What can you conclude about the properties of compounds and their elements?

Use the diagram below to answer questions 11 and 12.

11 In the diagram, how are valence electrons illustrated? How many valence electrons does each element have?

12 Describe a stable electron configuration. For each element above, how many electrons are needed to make a stable electron configuration?

Need Extra Help?												
If You Missed Question...	1	2	3	4	5	6	7	8	9	10	11	12
Go to Lesson...	1	1	3	3	3	2	2	3	1	2	1	1

78 Chapter 2 Standardized Test Practice

Chapter 2 Standardized Test Practice 79

Multiple Choice

1 A—Correct. B, C, D—The chemical formula CO_2 indicates the ratio of the atoms (1 carbon and 2 oxygen), the number of atoms in a molecule (3), and the types of elements in the compound (carbon and oxygen). However, this and other chemical formulas do not reveal the number of valence electrons in an atom.

2 C—Correct. A, B, D—An electron's energy level is determined by its distance from the nucleus. Electrons nearest the nucleus have the lowest levels of energy; electrons far from the nucleus have high energy levels. Electrons in the third energy level are second only to electrons in the fourth energy level in distance from the nucleus; therefore, electrons in the third energy level have the second highest energy level.

3 C—Correct. A, B, D—While atoms can become more stable by sharing or transferring valence electrons from one atom to another, they can also pool their valence electrons. Valence electrons in metals are not bonded to one atom.

4 A—Correct. B, C, D—The molecules of nonpolar compounds have covalent bonds. Consequently, these compounds are poor electrical conductors, lack the ability to dissolve easily in water, and have dull surfaces.

5 D—Correct. A, B, C—When sodium and chlorine bond and form sodium chloride, sodium loses its valance electron and chlorine gains it. In the new bond, both sodium and chlorine have eight valence electrons. An ionic bond has formed between Na^+ and Cl^- and each ion is stable.

6 D—Correct. A, B, C—When metals bond to nonmetals, they tend to form covalent bonds, which means that they share one or more pairs of valence electrons between atoms.

7 A—Correct. B, C, D—In the covalent bond that exists between oxygen and hydrogen in a water molecule, the oxygen atom attracts electrons more strongly than each hydrogen atom attracts electrons. Consequently, there is a slightly negative charge near the oxygen atom (1)

8 C—Correct. A, B, D—In ionic bonds, metal atoms give up electrons and nonmetal atoms gain them. The negatively and positively charged ions attract like magnets.

9 D—Correct. A, B, C—Group 18 noble gases are stable. They have eight valence electrons (with the exception of helium, which has two). Because atoms in these gases are stable, they neither react to nor bond with other atoms easily.

Constructed Response

10 Answers will vary. Possible answers:

Property	Rust	Iron	Oxygen
Color	Brown	Gray	Clear
Solid, liquid, or gas	Solid	Solid	Gas
Strength	Weak, crumbles	Strong	Does not apply
Usefulness	None	Very useful	Very useful

Conclusion: The properties of compounds differ from the properties of their component elements.

11 Answers will vary. Possible answer: The valence electrons appear in the outermost energy levels of the pictured elements (dark circles). Valence electrons: silicon (4) and phosphorus (5).

12 An atom with a stable electron configuration has either eight or two valence electrons. Electrons needed to form stable electron configurations: silicon (4) and phosphorus (3).

Answer Key

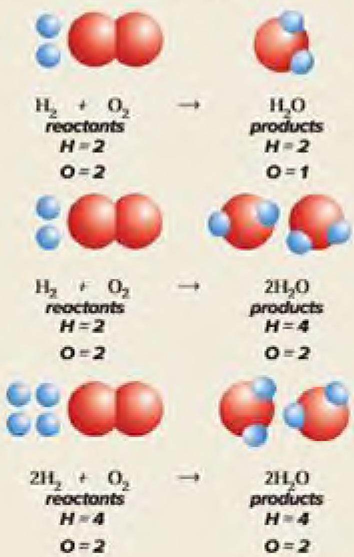
Question	Answer
1	A
2	C
3	C
4	A
5	D
6	D
7	A
8	C
9	D
10	See extended answer.
11	See extended answer.
12	See extended answer.
13	See extended answer.

Science Content Background

Lesson 1

Understanding Chemical Reactions

What is a chemical reaction? Every day we make many observations about reactions that occur in the world around us. What happens when we boil water? What happens when we freeze water? The physical characteristics of the water change, but the internal composition, two hydrogen atoms bonded to one oxygen atom, doesn't change no matter what physical change occurs. A chemical change is different. When atoms are taken apart and put back together in another way, a chemical change or chemical reaction has occurred. The atoms of two or more substances are being rearranged into a new substance. We see these changes often, although we might not realize what is happening; metal rusting or wood burning are both examples of chemical reactions that we might encounter.



Chemical Equations Every chemical reaction can be written as a chemical equation. An equation includes elements that make up substances. The original substances are called the reactants, since they react together and form new substances. The resulting substances are called the products, since they are produced by the reaction. Since elements are the building blocks for these substances, the elements in the reactants are the only elements that can be in the products. Elements cannot appear "out of nowhere," and two reacting elements cannot form a new element. Chemical equations must also be balanced. The total number of atoms of an element in the reactants must be equal to the total number of atoms of the same element in the products.

When we balance chemical equations, we are representing what has happened in the chemical reaction. To balance a chemical equation, coefficients are added in front of substances to balance the number of atoms in both the reactants and products. Although on paper it seems as though we are randomly placing coefficients, if balanced properly, the new equation is simply representing what happened in the reaction.

Science Content Background

Lesson 2

Types of Chemical Reactions

Classify Chemical Reactions by Substances It is human nature to want to classify items into categories to help understand their composition and how the items relate to one another. In this lesson, chemical reactions are classified into four main categories: synthesis, decomposition, replacement reactions, and combustion. Within replacement reactions, there are single replacement and double replacement reactions. This category is based on how the atoms of the elements change from reactants to products. For example, in synthesis, two or more substances combine and form a new substance; in other words, the atoms in the substances (reactants) break apart and then combine in a new way and form new substances (products).

Synthesis Reactions

Examples:

$2Na + Cl_2 \rightarrow 2NaCl$
$2H_2 + O_2 \rightarrow 2H_2O$
$H_2O + SO_3 \rightarrow H_2SO_4$

Decomposition Reactions

Examples:

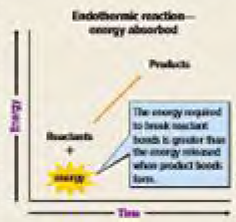
$CaCO_3 \rightarrow CaO + CO_2$
$2H_2O \rightarrow 2H_2 + O_2$
$2KClO_3 \rightarrow 2KCl + 3O_2$

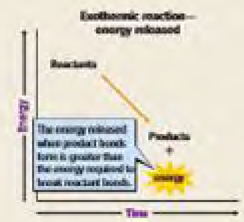
Lesson 3

Energy Changes and Chemical Reactions

Classify Chemical Reactions by Energy Energy is involved when substances break apart and come back together. This is called *chemical energy*. In this lesson, chemical reactions are classified by the transfer of energy associated with them—absorption or release. Chemical reactions that absorb energy are called endothermic reactions. Chemical reactions that release energy are called exothermic reactions.

Reaction Rates The speed at which a chemical reaction takes place is called its rate. Some chemical reactions are very fast, such as the reaction that causes an explosion in fireworks. Other chemical reactions are slow, such as the rusting of metal. The rate of a chemical reaction can be changed by adjusting some factors. For example, by increasing the surface area of each of the substances, increasing the temperature, or increasing the concentration or pressure of the substances, you can cause the reaction to occur more quickly.





Strand Map

Required Background Knowledge

To understand the Key Concepts of this chapter, students should have the following background knowledge:

* Materials may be composed of parts that are too small to be seen without magnification.

* A lot of different materials can be made from the same basic materials.

* When a new material is made by combining two or more materials, it has properties that are different from the original materials.

* No matter how many parts of an object are assembled, the weight of the whole object made is always the same as the sum of the parts.

* Things can be done to materials to change some of their properties, but not all materials respond the same way to what is done to them.

* American Association for the Advancement of Science. (1993). Benchmarks for Science Literacy. New York: Oxford University Press.

Lesson 1
Understanding Chemical Reactions

1 There are several signs that a chemical reaction might have occurred, including a change of temperature, a release of light, a release of gas, a change in color or odor, and the formation of a solid from two liquids.

2 In a chemical reaction, atoms of reactants rearrange and form products.

3 The total mass of all of the reactants is equal to the total mass of all the products in a reaction.

Lesson 2
Types of Chemical Reactions

5 Most chemical reactions fit into one of a few main categories—synthesis, decomposition, combustion, and single or double-replacement.

4 Synthesis reactions create one product. Decomposition reactions start with one reactant. Single- and double-replacement reactions involve replacing one element or group of atoms with another element or group of atoms. Combustion reactions involve a reaction between one reactant and oxygen and release thermal energy.

Lesson 3
Energy Changes and Chemical Reactions

6 Chemical reactions always involve breaking bonds, which requires energy, and forming bonds, which releases energy.

7 n an endothermic reaction, the reactants contain less energy than the products. In an exothermic reaction, the reactants contain more energy than the products.

8 The rate of a chemical reaction can be increased by increasing the surface area, the temperature, or the concentration of the reactants, or by adding a catalyst.

Identifying Misconceptions

It's a Process

Find Out What Students Think

Students may think that...

... the creation of new substances in chemical reactions simply happens, rather than through the substances breaking apart and forming new substances. Students may also think that reactions can destroy substances, removing some items from existence, rather than rearranging the reactants into a different form.

Discussion

Explain that new elements cannot appear in the product of a chemical reaction. The only elements that are present are the ones in the substances of the reactants. The substances have broken apart and the elements are bonded differently and form new substances.

Have students think about the chemical reaction of baking bread. **Ask:** What kinds of ingredients are in bread? **flour, water, sugar, yeast** After the bread is baked, is there an ingredient that magically appeared? **no** Explain that the baking of the bread is a chemical reaction. The substances in the reactants, or the ingredients, have changed and formed new bonds that changed the dough into bread.

Promote Understanding

Activity Have students represent the combustion of methane using an equation and a clay model.

1. Write the chemical equation for the combustion of methane on the board or overhead:
   $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
2. Have students represent the reactants using different colored clay for carbon, hydrogen, and oxygen. Students should show the two substances, methane (CH_4) and oxygen ($2O_2$) as two separate connected balls of clay.
3. Then have students take the balls of clay apart and rearrange them so they represent the products, carbon dioxide (CO_2) and water ($2H_2O$).
4. Discuss how the number of atoms of each element did not change. They did not have to make any new balls of clay to represent the product. There were no new elements in the products; the elements only were rearranged.

Catalysts and Inhibitors

Find Out What Students Think

Students may think that...

... all catalysts and inhibitors speed up or slow down a reaction at the same rate.

Discussion

Remind students that a catalyst is a substance that speeds up a reaction. An inhibitor is a substance that slows down a reaction. Point out that there are many different catalysts that can speed up the same reaction; similarly, there are many different inhibitors that can slow down the same reaction.

Have students think about food, such as bread. Explain that without an inhibitor, the bread would begin to decompose very quickly. **Ask:** What are some different inhibitors that are used to help slow the decomposition of bread? **Students may answer that preservatives will slow decomposition.**

Promote Understanding

Activity Remind students that different catalysts affect the same reaction in different ways. Show students two test tubes of hydrogen peroxide, each containing a few drops of liquid soap. Tell students that the hydrogen peroxide, $2H_2O_2$, decomposes into water and oxygen, or $2H_2O$ and O_2. Have students brainstorm different ways they may be able to observe this observation. Ultimately have them understand that oxygen is released as small bubbles and water is left behind. Students should be made aware that the reaction is occurring VERY slowly as they observe the two test tubes, so slowly that it is barely visible.

Next, show students two catalysts that will speed up the reaction, potassium iodide and an enzyme in a potato. Discuss whether students think that each catalyst will speed up the reaction at the same rate or if one catalyst will cause the decomposition more quickly. Explain that the more bubbles in the reaction, the more quickly the reaction is occurring. Pour the potassium iodide into one test tube and place a piece of potato in the other. Have students observe which reaction rate is changed the most. Remind students that both the potassium iodide and the potato enzyme are catalysts and that in both test tubes the SAME reaction was occurring. The different catalysts caused a different change in reaction rates.

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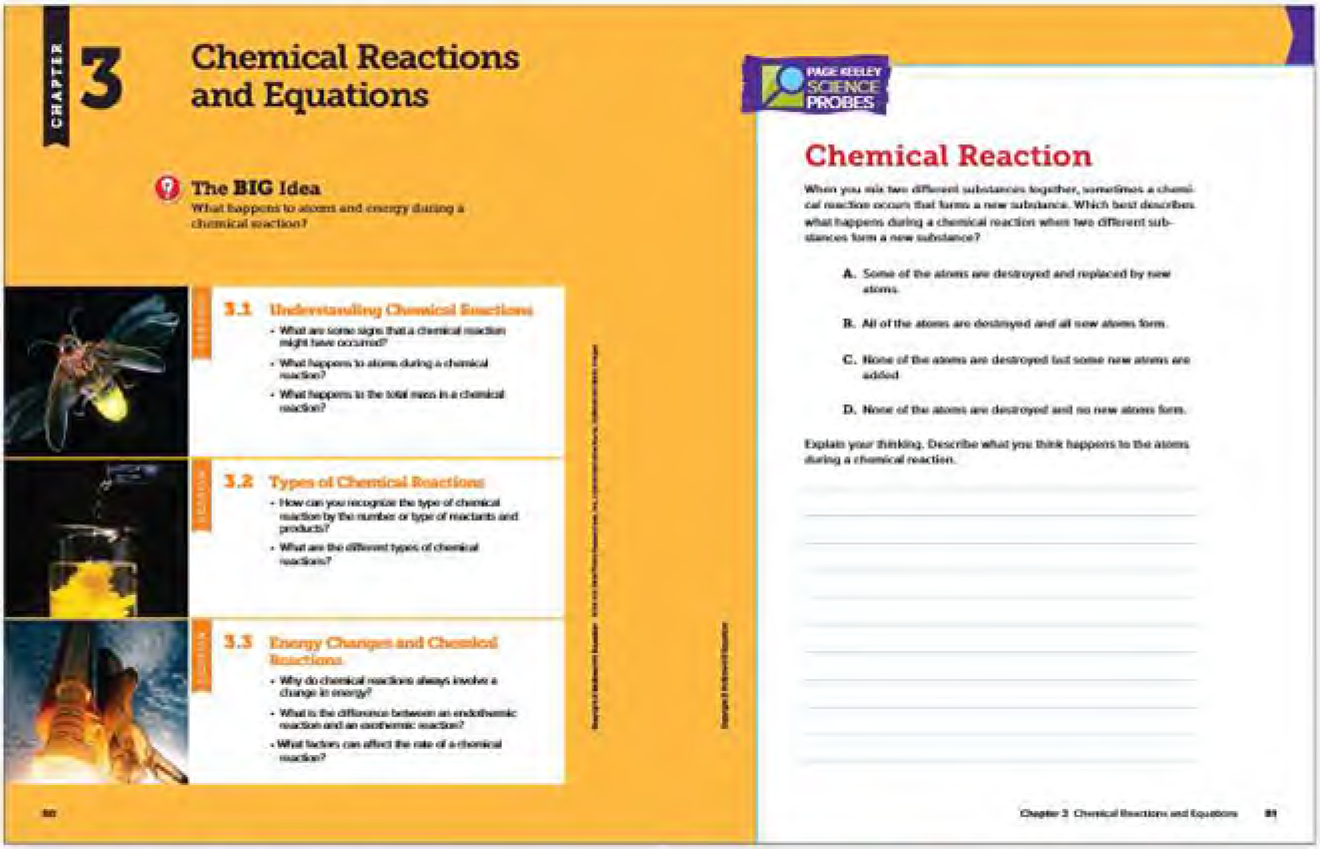

CHAPTER 3

Chemical Reactions and Equations

The BIG Idea
What happens to atoms and energy during a chemical reaction?

3.1 Understanding Chemical Reactions
- What are some signs that a chemical reaction might have occurred?
- What happens to atoms during a chemical reaction?
- What happens to the total mass in a chemical reaction?

3.2 Types of Chemical Reactions
- How can you recognize the type of chemical reaction by the number or type of reactants and products?
- What are the different types of chemical reactions?

3.3 Energy Changes and Chemical Reactions
- Why do chemical reactions always involve a change in energy?
- What is the difference between an endothermic reaction and an exothermic reaction?
- What factors can affect the rate of a chemical reaction?

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PAGE KEELEY SCIENCE PROBES

Chemical Reaction

When you mix two different substances together, sometimes a chemical reaction occurs that forms a new substance. Which best describes what happens during a chemical reaction when two different substances form a new substance?

A. Some of the atoms are destroyed and replaced by new atoms.

B. All of the atoms are destroyed and all new atoms form.

C. None of the atoms are destroyed but some new atoms are added.

D. None of the atoms are destroyed and no new atoms form.

Explain your thinking. Describe what you think happens to the atoms during a chemical reaction.

Chapter 3 Chemical Reactions and Equations 81

Chemical Reactions and Equations

The BIG Idea

There are no right or wrong answers to these questions. Write student-generated questions produced during the discussion on chart paper and return to them throughout the chapter.

Guiding Questions

AL Do you think there is anything produced besides air when the airbag is deployed?	*Students should realize that air is only one product of the chemical reaction. Other substances form as well.*
OL When chemicals are mixed together and form a gas, do you think any energy is released? Why or why not?	*Yes; explosions are often the result of chemical mixing. This question requires students to think about the connection between chemical reactions and energy.*
BL After the airbag is deployed, it stays inflated only for a short time. What do you think happens to cause it to stop inflating?	*Sample answer: Gas leaks out of the bag; there are no more chemicals left to make the gas. (This question should encourage students to think about how the substances used to produce the gas that inflates the airbag can be used up.)*

PAGE KEELEY SCIENCE PROBES

Chemical Reaction

Answers to the Page Keeley Science Probe can be found in the Teacher's Edition of the *Activity Lab Workbook.*

Get Ready to Read

What do you think?

Use this anticipation guide to gauge students' background knowledge and preconceptions about chemical reactions and equations. At the end of each lesson, ask students to read and evaluate their earlier responses. Students should be encouraged to change any of their responses.

Anticipation Set for Lesson 1

1. If a substance bubbles, you know a chemical reaction is occurring.

Disagree. When water boils, it also bubbles. Bubbling can be a sign of a chemical reaction but it is not proof of a reaction. The only way to know if a reaction has occurred is to test the properties of the reactants and the products to see if new substances formed.

2. **During a chemical reaction, some atoms are destroyed and new atoms are made.**

   Disagree. During a chemical reaction, no atoms are created or destroyed. Atoms are just rearranged.

Anticipation Set for Lesson 2

3. **Reactions always start with two or more substances that react with each other.**

   Disagree. One type of reaction, decomposition, starts with one substance that breaks down into two or more substances.

4. **Water can be broken down into simpler substances.**

   Agree. Water can be broken down into its component elements—hydrogen and oxygen.

Anticipation Set for Lesson 3

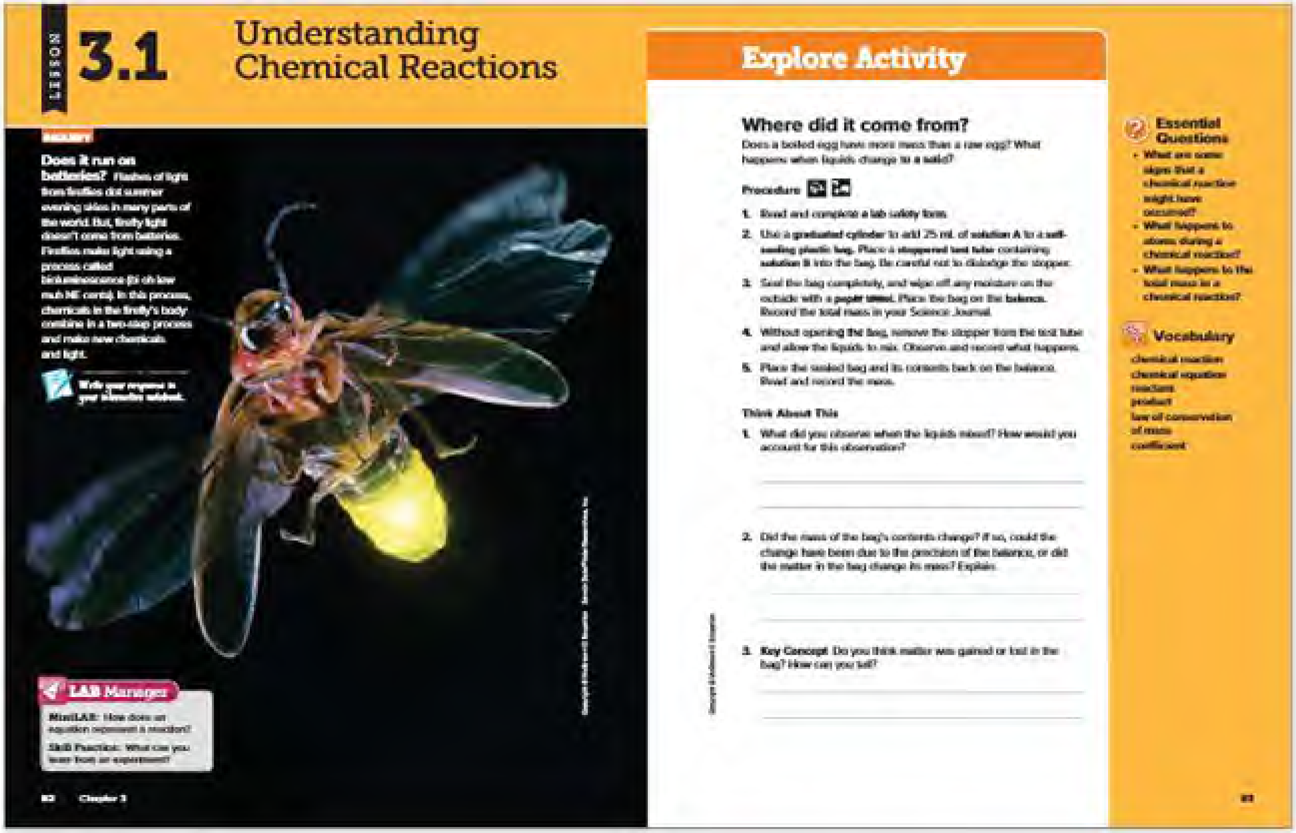
5. **Reactions that release energy require energy to get started.**

   Agree Reactions that release energy still require activation energy to start.

6. **Energy can be created in a chemical reaction.**

   Disagree. Energy can be released in a chemical reaction, but it can't be created. It changes form from chemical energy to another form, such as thermal energy.

Teacher Notes



LESSON 3.1 Understanding Chemical Reactions

INQUIRY

Does it run on batteries? Flashes of light from fireflies dot summer evening skies in many parts of the world. But, firefly light doesn't come from batteries. Fireflies make light using a process called bioluminescence (bi oh law muh NE cents). In this process, chemicals in the firefly's body combine in a two-step process and make new chemicals and light.

Write your response in your interactive notebook.

LAB Manager

MiniLAB: How does an equation represent a reaction?

Skill Practice: What can you learn from an experiment?

82 Chapter 3

Explore Activity

Where did it come from?

Does a boiled egg have more mass than a raw egg? What happens when liquids change to a solid?

Procedure

1. Read and complete a lab safety form.
2. Use a **graduated cylinder** to add 25 mL of **solution A** to a **self-sealing plastic bag**. Place a **stoppered test tube** containing **solution B** into the bag. Be careful not to dislodge the stopper.
3. Seal the bag completely, and wipe off any moisture on the outside with a **paper towel**. Place the bag on the **balance**. Record the total mass in your Science Journal.
4. Without opening the bag, remove the stopper from the test tube and allow the liquids to mix. Observe and record what happens.
5. Place the sealed bag and its contents back on the balance. Read and record the mass.

Think About This

1. What did you observe when the liquids mixed? How would you account for this observation?
2. Did the mass of the bag's contents change? If so, could the change have been due to the precision of the balance, or did the matter in the bag change its mass? Explain.
3. **Key Concept** Do you think matter was gained or lost in the bag? How can you tell?

Essential Questions

- What are some signs that a chemical reaction might have occurred?
- What happens to atoms during a chemical reaction?
- What happens to the total mass in a chemical reaction?

Vocabulary

chemical reaction
chemical equation
reactant
product
law of conservation of mass
coefficient

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INQUIRY

About the Photo **Does it run on batteries?** This firefly is not the only organism that can release light energy. Organisms such as mushrooms, jellyfish, squid, glow worms, and marine plankton also are known to release light energy. Some of the organisms rely on factors other than bioluminescence. For example, Hawaiian squid contain glowing bacteria. In this lesson, students will learn the properties that may be present after a chemical change has occurred. The release of light is one property.

Guiding Questions

AL **What chemical process do fireflies use to release light?**	*bioluminescence*
OL **How do you think organisms like fireflies are able to release light?**	*When chemicals in the organism's body react, the reaction releases light.*
BL **Which vocabulary words could be used to explain the chemicals present before bioluminescence occurs? Which could be used to explain the chemicals after?**	*Sample answer: Reactants are the chemicals that react. Products are the chemicals present after the reaction.*

LAB Manager

Labs can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

What is a product?

1. Have students name some places where they might have used the word *product*, such as in mathematics or when something is made. Students might mention that a product in math is the answer to a multiplication problem or that a factory might use wool and looms to produce sweaters.
2. Ask students to think about the words *product*, *react*, and *substances*, and create a math sentence using these words. An example of this would be: One substance reacts (+) with another substance and creates (=) a new product.
3. Ask students to read their sentences aloud.
4. Discuss the meanings of the words based upon the context clues in their sentences.

Explore Activity

Where did it come from?

Prep: *15 min* **Class:** *15–20 min*

Purpose
To observe the conservation of mass during a chemical change

Materials
Students Pairs: graduated cylinder; 25 mL of solution A (copper sulfate, $CuSO_4$, available at pet stores as a snail inhibitor, or garden shops as a root killer); 1-L self-sealing plastic bag, stoppered test tube containing 25 mL of solution B (sodium carbonate, Na_2CO_3, available at a grocery store as washing soda); balance, paper towel

Before You Begin

- Sodium bicarbonate (baking soda) can be substituted for solution B. If you don't want students handling a glass test tube inside a plastic bag, you may use a second plastic bag for solution B.
- For Solution A, mix 25 g CuSO4 with distilled water to make 1 L. For Solution B, mix 10.6 g of Na2CO3 with water to make 1 L. Prepare a securely stoppered test tube containing 25 mL of solution B for each team.

Guide the Investigation
As they read the introduction, ask students to predict the mass of a raw egg after it was hard cooked. Encourage students to explain their reasoning.
Troubleshooting: If students use a triple-beam balance, instruct them to find the mass before mixing. Ask students to remove the stopper and mix the solutions while leaving the bag sealed and on the balance.

Think About This

1. A white solid formed. Unless students already know about chemical changes, they may not be able to explain what happened. Encourage them to speculate.
2. The mass of the bag should remain the same. There may be a small difference in the mass before and after mixing. Remind students that a balance may not read the same, even for the same object. Explain that the amount of change, if there was any, is too small to be sure it wasn't caused by the balance.
3. **Key Concept** Students should conclude that matter was not gained or lost because the mass of the matter did not change.

Teacher Notes

Before reading this lesson, write down what you already know in the first column. In the second column, write down what you want to learn. After you have completed this lesson, write down what you learned in the third column.

What I Know	What I Want to Learn	What I Learned

Changes in Matter

When you put liquid water in a freezer, it changes to solid water, or ice. When you pour brownie batter into a pan and bake it, the liquid batter changes to a solid, too. In both cases, a liquid changes to a solid. Are these changes the same?

Physical Changes

Recall that matter can undergo two types of changes: chemical or physical. A physical change does not produce new substances. The substances that exist before and after the change are the same, although they might have different physical properties. This is what happens when liquid water freezes. Its physical properties change from a liquid to a solid, but the water, H_2O, does not change into a different substance. Water molecules are always made up of two hydrogen atoms bonded to one oxygen atom regardless of whether they are solid, liquid, or gas.

Chemical Changes

Recall that during a chemical change, one or more substances change into new substances. The starting substances and the substances produced have different physical and chemical properties. For example, when brownie batter bakes, a chemical change occurs. Many of the substances in the baked brownies are different from the substances in the batter. As a result, baked brownies have physical and chemical properties that are different from those of brownie batter.

A chemical change also is called a chemical reaction. These terms mean the same thing. A **chemical reaction** *is a process in which atoms of one or more substances rearrange to form one or more new substances.* In this lesson, you will read what happens to atoms during a reaction and how these changes can be described using equations.

Signs of a Chemical Reaction

How can you tell if a chemical reaction has taken place? You have read that the substances before and after a reaction have different properties. You might think that you could look for changes in properties as a sign that a reaction occurred. In fact, changes in the physical properties of color, state of matter, and odor are all signs that a chemical reaction might have occurred. Another sign of a chemical reaction is a change in energy. If substances get warmer or cooler or if they give off light or sound, it is likely that a reaction has occurred. Some signs that a chemical reaction might have occurred are shown in **Figure 1**.

However, these signs are not proof of a chemical change. For example, bubbles appear when water boils. But, bubbles also appear when baking soda and vinegar react and form carbon dioxide gas. How can you be sure that a chemical reaction has taken place? The only way to know is to study the chemical properties of the substances before and after the change. If they have different chemical properties, then the substances have undergone a chemical reaction.

Key Concept Check

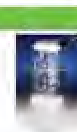
1. What are some signs that a chemical reaction might have occurred?

Figure 1 You can detect a chemical reaction by looking for changes in properties and changes in energy of the substances that reacted.

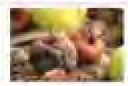
Change in Properties

Change in color
Bright copper changes to green when the copper reacts with certain gases in the air.

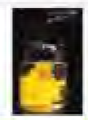
Formation of bubbles
Bubbles of carbon dioxide form when baking soda is added to vinegar.



Change in odor
When food burns or rots, a change in odor is a sign of chemical change.

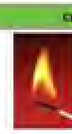


Formation of a precipitate
A precipitate is a solid formed when two liquids react.



Change in Energy

Warming or cooling
Thermal energy is either given off or absorbed during a chemical change.



Release of light
A firefly gives off light as the result of a chemical change.

Changes in Matter

Remind students that matter is classified as solid, liquid, or gas. Review the definitions for the states of matter.

Physical and Chemical Changes

When you mix brownie ingredients together, a physical change occurs. When the brownie batter bakes, the thermal energy from the oven causes a chemical change. In chemical changes, atoms in substances rearrange resulting in new chemical properties. Physical changes do not produce new substances.

Guiding Questions

OL **What types of properties change during a chemical reaction?**	*During a chemical reaction, both chemical and physical properties change.*
BL **How do you know that baking brownies involves a chemical reaction?**	*The starting substances and the substances produced have different physical and chemical properties.*

Signs of a Chemical Reaction

Students must be able to identify signs that a chemical reaction has occurred in order to determine if a reaction is chemical or physical. As they read the section and review **Figure 1**, instruct students to think about brownie batter and baked brownies and how color, temperature, smell, and texture changed. Ask these questions to check understanding.

Guiding Questions

AL **Why is the fireflies' release of light a sign of a chemical change?**	*Giving off light suggests a release of energy.*
OL **What are some signs that a chemical reaction might have occurred?**	*Signs of a chemical reaction include production of an odor, precipitate, or gas; a change in energy; or a change in color.*
BL **How do you know that baking brownies involves a chemical change?**	*The starting substances and the substances produced have different physical and chemical properties.*

Visual Literacy: Changes in Property and Energy

Review **Figure 1** with students to help them understand that some substances react chemically when they come in contact with each other. Ask the following questions as you discuss the figure.

Ask: For each of the images in the top row, what two substances might be chemically reacting? *The copper in the Statue of Liberty is reacting with gases in the air; the baking soda is reacting with the vinegar.*

Ask: What might cause a change in the odor of food? *food reacting with gases in the air or substances in food reacting with one another*

Ask: Why might a chemical reaction be present in the two images shown under Changes in Energy? *The match is giving off light energy and thermal energy. The animal is giving off light energy.*

Ask: Will substances become warm or cool when energy is absorbed? Why do you think so? *Warmer; possible explanation: If thermal energy is being absorbed, the item will warm.*

Differentiated Instruction

AL **Chemical Reaction Clue Finder** Instruct students to create clue cards. Have them use the chart in **Figure 1** as a guide. Ask students to write a question on one side of an index card and hints and examples on the other side. Have the class use these cards to assess the chapter and lesson opener photos and explain to each other which signs of a chemical reaction are present in each.

BL **Making Chemical Bonds** Have students research the chemical reaction involved in bioluminescence. Ask students to identify the substances present in the chemical reaction or reactions that result in a firefly emitting light, as shown in the lesson opener photo. Have them work together to create a poster board that shows the compounds before and after the reaction. They can use **Figure 2** as a guide.

Teacher Toolbox

Reading Strategy

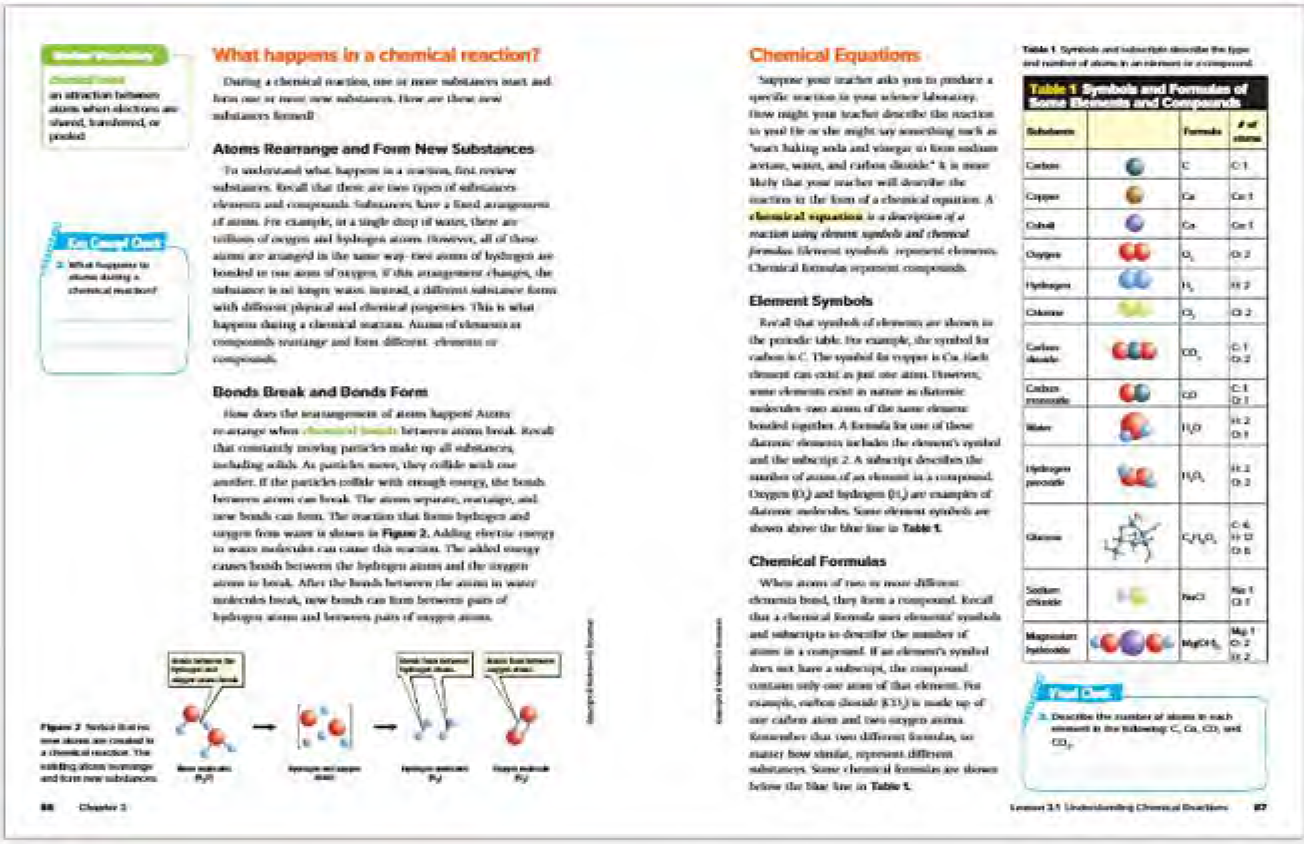
Questions Have students reread the sections **Atoms Rearrange and Form New Substances** and **Bonds Break and Bonds Form**. Ask each student to create an original question for each section that can be answered from the reading. Students trade their questions with a partner and then answer their partner's questions.

Fun Fact

Atom Smasher Chemical reactions break bonds between atoms. However, to break apart an atom, you need an atom smasher. An atom smasher, otherwise known as a particle accelerator, takes part of an atom, speeds it up to nearly the speed of light, and smashes it into another atom. This releases subatomic particles.

Real-World Science

Onions Make Us Cry The familiar onion smell is the result of a chemical reaction that occurs when you cut an onion. The reaction produces a type of sulfur compound and releases an acid-like chemical that can irritate your eyes.



What happens in a chemical reaction?

During a chemical reaction, one or more substances react and form one or more new substances. How are these new substances formed?

Atoms Rearrange and Form New Substances

To understand what happens in a reaction, first review substances. Recall that there are two types of substances: elements and compounds. Substances have a fixed arrangement of atoms. For example, in a single drop of water, there are trillions of oxygen and hydrogen atoms. However, all of these atoms are arranged in the same way: two atoms of hydrogen are bonded to one atom of oxygen. If this arrangement changes, the substance is no longer water. Instead, a different substance forms with different physical and chemical properties. This is what happens during a chemical reaction. Atoms of elements or compounds rearrange and form different elements or compounds.

Bonds Break and Bonds Form

How does the rearrangement of atoms happen? Atoms rearrange when chemical bonds between atoms break. Recall that constantly moving particles make up all substances, including solids. As particles move, they collide with one another. If the particles collide with enough energy, the bonds between atoms can break. The atoms separate, rearrange, and new bonds can form. The reaction that forms hydrogen and oxygen from water is shown in **Figure 2**. Adding electric energy to water molecules can cause this reaction. The added energy causes bonds between the hydrogen atoms and the oxygen atoms to break. After the bonds between the atoms in water molecules break, new bonds can form between pairs of hydrogen atoms and between pairs of oxygen atoms.

Figure 2 Notice that no new atoms are created in a chemical reaction. The existing atoms rearrange and form new substances.

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Chemical Equations

Suppose your teacher asks you to produce a specific reaction in your science laboratory. How might your teacher describe the reaction to you? He or she might say something such as "react baking soda and vinegar to form sodium acetate, water, and carbon dioxide." It is more likely that your teacher will describe the reaction in the form of a chemical equation. A **chemical equation** *is a description of a reaction using element symbols and chemical formulas.* Element symbols represent elements. Chemical formulas represent compounds.

Element Symbols

Recall that symbols of elements are shown in the periodic table. For example, the symbol for carbon is C. The symbol for copper is Cu. Each element can exist as just one atom. However, some elements exist in nature as diatomic molecules: two atoms of the same element bonded together. A formula for one of these diatomic elements includes the element's symbol and the subscript 2. A subscript describes the number of atoms of an element in a compound. Oxygen (O_2) and hydrogen (H_2) are examples of diatomic molecules. Some element symbols are shown above the blue line in **Table 1**.

Chemical Formulas

When atoms of two or more different elements bond, they form a compound. Recall that a chemical formula uses elements' symbols and subscripts to describe the number of atoms in a compound. If an element's symbol does not have a subscript, the compound contains only one atom of that element. For example, carbon dioxide (CO_2) is made up of one carbon atom and two oxygen atoms. Remember that two different formulas, no matter how similar, represent different substances. Some chemical formulas are shown below the blue line in **Table 1**.

Table 1 Symbols and subscripts describe the type and number of atoms in an element or a compound.

Table 1 Symbols and Formulas of Some Elements and Compounds

Substance		Formula	# of atoms
Carbon		C	C: 1
Copper		Cu	Cu: 1
Cobalt		Co	Co: 1
Oxygen		O_2	O: 2
Hydrogen		H_2	H: 2
Chlorine		Cl_2	Cl: 2
Carbon dioxide		CO_2	C: 1 O: 2
Carbon monoxide		CO	C: 1 O: 1
Water		H_2O	H: 2 O: 1
Hydrogen peroxide		H_2O_2	H: 2 O: 2
Glucose		$C_6H_{12}O_6$	C: 6 H: 12 O: 6
Sodium chloride		NaCl	Na: 1 Cl: 1
Magnesium hydroxide		$Mg(OH)_2$	Mg: 1 O: 2 H: 2

3. Describe the number of atoms in each element in the following: C, Cu, CO, and CO_2.

Lesson 3.1 Understanding Chemical Reactions 87

What happens in a chemical reaction?

Review the definition of a substance. Use **Figure 2** to point out that water is a substance, composed of hydrogen and oxygen atoms. These atoms could be involved in many of the chemical reactions shown in **Figure 1**.

Atoms Rearrange and Form New Substances

Reinforce the idea that no new atoms form in a chemical reaction, only new substances. Point out that in **Figure 2**, the groupings of blue and red atoms change but the number of atoms before and after the reaction does not.

Guiding Questions

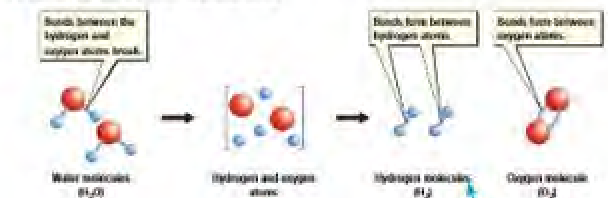
AL **How can you distinguish one substance from another?**	*You can distinguish substances by their physical properties.*
OL **What happens if you remove a hydrogen atom from a water molecule?**	*It is no longer a water molecule.*
BL **What is the difference between a physical change and a chemical change in water molecules?**	*A water molecule's structure does not change during a physical change. In a chemical change, a water molecule's structure changes and it is no longer a water molecule.*

Visual Literacy: Bonds Break and Bonds Form

Link this section with the one above. Explain that bonds between atoms must break before atoms rearrange and form new substances.

Ask students to note the two bonds on the left image in **Figure 2**. Explain that two hydrogen atoms and one oxygen atom bond and form a water molecule. Only a chemical change can break this bond. When that happens, the atoms rearrange themselves.

Ask: What happens to atoms during a chemical reaction? *Atoms rearrange and form substances.*



Ask: How can you describe the bond between the four hydrogen and two oxygen atoms? *One oxygen atom bonds with two hydrogen atoms.*

Ask: How has the bond between the hydrogen and oxygen atoms changed? *The bonds are broken. The atoms are separate.*

Ask: How can you describe the new bonds between oxygen atoms and hydrogen atoms? *Two bonds are between two oxygen atoms and one bond between two hydrogen atoms.*

Review Vocabulary

chemical bond

Ask: **What is a bond?** *A bond is an attraction between two atoms.*

Ask: **What parts of the atoms of a water molecule form its chemical bonds?** *There is an attraction among the valence electrons in the atoms of the molecule.*

Ask: **What kind of change could break these bonds?** *A chemical change can break a chemical bond.*

Chemical Equations

Chemical equations represent chemical reactions. Compare a simple math equation to a simple chemical equation to facilitate understanding. Explain that the original substances are to the left side of the arrow. The new substances formed are to the right side of the arrow.

Element Symbols

Use **Table 1** to review how elements are represented in chemical equations. Note that some common elements, like oxygen, hydrogen, and chlorine, are diatomic molecules. To help students understand chemical equations ask them the following questions.

Guiding Questions

AL **What are examples of symbols that represent an element and a compound?**	*Possible answers include C, Cu, and Co for elements; H_2O, H_2O_2 and NaCl for compounds.*
OL **Why are the elements hydrogen, chlorine, and oxygen represented as H_2, Cl_2 and O_2?**	*These elements are diatomic molecules.*
BL **Why is the chemical formula 2C NOT an example of a diatomic molecule?**	*The formula 2C has a coefficient of 2, and no subscript, so we know that it's not a diatomic molecule.*

Chemical Formulas

Use **Table 1** to review with students the differences between elements and compounds. Show students how colors, capitalization, and numbers can help them distinguish elements from compounds.

Visual Literacy: Symbols and Formulas of Some Elements and Compounds

Students must be able to determine which elements make up the formulas in order to read and balance chemical equations. To assess understanding, ask these questions about the last compound in **Table 1**.

Ask: **How can you tell how many atoms are in this chemical compound?** *First, determine the elements in the compound. Then count the number of atoms of each element. The subscript indicates the number of atoms.*

$Mg(OH)_2$

Ask: **What does it mean that Mg has no subscript in this chemical formula?** *If an element no subscript that means the subscript is 1. There is only one atom of magnesium in the formula.*

Differentiated Instruction

AL **Annotate a Chemical Equation** Have students annotate the chemical equation $H_2 + O_2 \rightarrow H_2O_2$. Students should identify the elements in the equation and determine if any of the elements contain diatomic molecules.

BL **Breaking and Bonding** Have student work in pairs. Ask them to create the stills for a five-second video that shows the chemical equation $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$ (photosynthesis). Have them use a periodic table to identify each element. The video stills should show where the bonds break and where the new bonds form between atoms. Students can use **Figure 2** as a guide.

Teacher Toolbox

Teacher Demo

Chemical Reactions Show students a simple chemical reaction, such as the reaction of baking soda (a base, NaHCO3) and vinegar (an acid, HC2H3O). Discuss how you tell that a chemical reaction has occurred. Write the element symbols and chemical formulas needed to represent the reaction on the board. Finally show students the chemical equation that represents the reaction.

$$HC_2H_3O_2 + NaHCO_3 \rightarrow NaC_2H_3O_2 + H_2CO_3$$

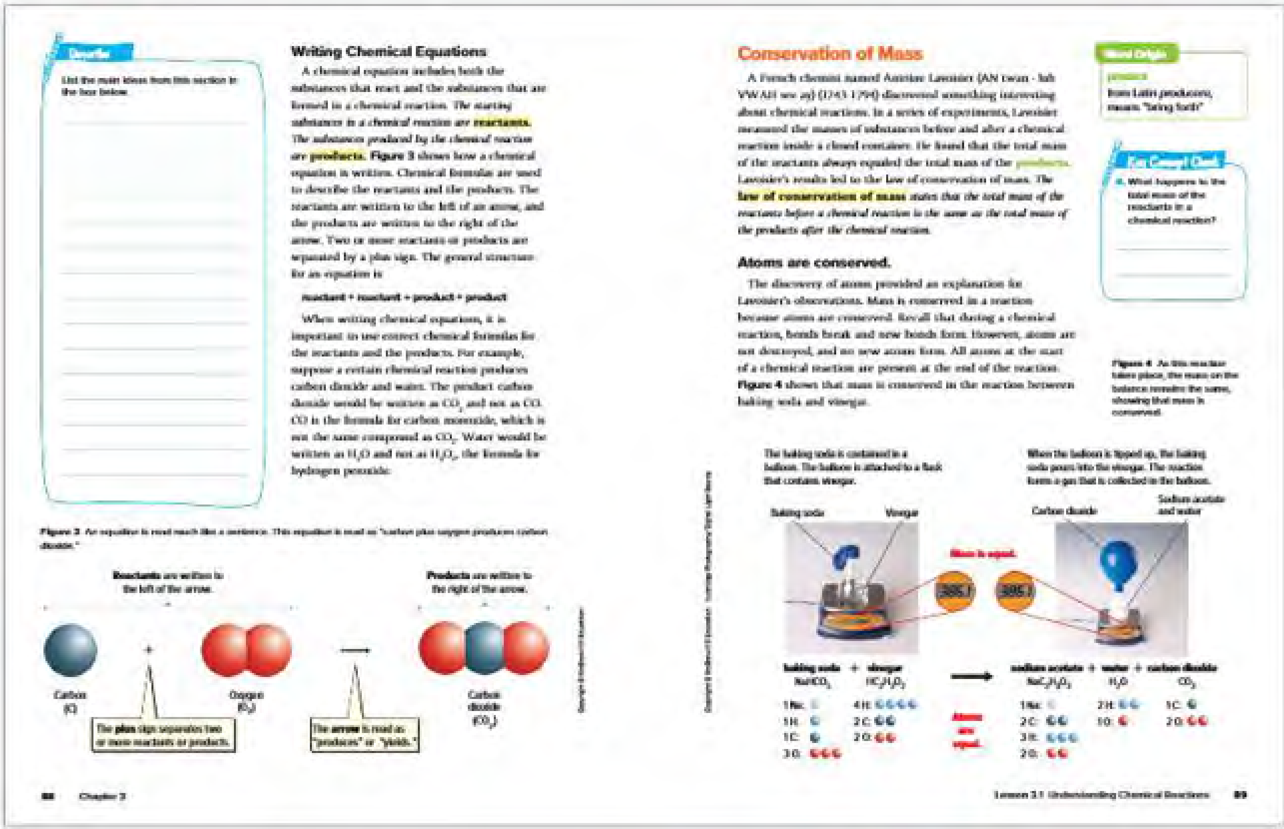
Math Skills

Just Like an Equation Solve a typical math equation, such as 1 + 2 = 3. To solve they must add 2 to 1. Compare this simple equation to the creation of carbon dioxide in **Figure 3**. Do the same with 4 + 2 = 6 and the creation of hydrogen and oxygen in **Figure 2**. Explain that chemical formulas work just like math formulas.

Careers in Science

Chemical Engineers Chemical engineers apply their knowledge of chemistry to make useful products. They research and then mix elements and compounds and create everything from household items, such as soap and toothpaste, to alternative fuels for cars and super fuels for spacecrafts.

Ask: **Describe the number of atoms in each element in the following: C, Co, CO, and CO_2.** *C = 1 carbon atom; Co = 1 cobalt atom; CO = 1 carbon atom and 1 oxygen atom; CO_2 = 1 carbon atom and 2 oxygen atoms.*



Describe

List the main ideas from this section in the box below.

Writing Chemical Equations

A chemical equation includes both the substances that react and the substances that are formed in a chemical reaction. *The starting substances in a chemical reaction are* **reactants.** *The substances produced by the chemical reaction are* **products.** **Figure 3** shows how a chemical equation is written. Chemical formulas are used to describe the reactants and the products. The reactants are written to the left of an arrow, and the products are written to the right of the arrow. Two or more reactants or products are separated by a plus sign. The general structure for an equation is

reactant + reactant → product + product

When writing chemical equations, it is important to use correct chemical formulas for the reactants and the products. For example, suppose a certain chemical reaction produces carbon dioxide and water. The product carbon dioxide would be written as CO_2 and not as CO. CO is the formula for carbon monoxide, which is not the same compound as CO_2. Water would be written as H_2O and not as H_2O_2, the formula for hydrogen peroxide.

Figure 3 An equation is read much like a sentence. This equation is read as "carbon plus oxygen produces carbon dioxide."

Conservation of Mass

A French chemist named Antoine Lavoisier (AN twan · luh VWAH see ay) (1743–1794) discovered something interesting about chemical reactions. In a series of experiments, Lavoisier measured the masses of substances before and after a chemical reaction inside a closed container. He found that the total mass of the reactants always equaled the total mass of the products. Lavoisier's results led to the law of conservation of mass. *The* **law of conservation of mass** *states that the total mass of the reactants before a chemical reaction is the same as the total mass of the products after the chemical reaction.*

Word Origin

products

from Latin *producere*, means "bring forth"

Key Concept Check

4. What happens to the total mass of the reactants in a chemical reaction?

Atoms are conserved.

The discovery of atoms provided an explanation for Lavoisier's observations. Mass is conserved in a reaction because atoms are conserved. Recall that during a chemical reaction, bonds break and new bonds form. However, atoms are not destroyed, and no new atoms form. All atoms at the start of a chemical reaction are present at the end of the reaction. **Figure 4** shows that mass is conserved in the reaction between baking soda and vinegar.

Figure 4 As this reaction takes place, the mass on the balance remains the same, showing that mass is conserved.

Writing Chemical Equations

Write the equation in **Figure 3** on the board and label it *carbon plus oxygen produces carbon dioxide*. Ask students to note the reactant molecules and product molecules. Erase the subscript from carbon dioxide and ask students to explain why the sentence no longer explains the reaction.

Guiding Questions

AL **What does the arrow in a chemical equation mean?**	*The arrow shows the reader that the reactants become products.*
OL **Why is it important to correctly use subscripts in chemical equations?**	*Some compounds differ just by the number of atoms of each element.*
BL **How can you check an equation to be sure all of the chemical formulas are correct?**	*Check the types and number of elements on both sides of the equation.*

Conservation of Mass

As students analyze chemical equations for chemical reactions, they should begin to realize that the equations are balanced. Have them note that in all of the chemical reactions in the chapter, the number of atoms in the reactants always equals the number of atoms in the products. To help students understand the law of conservation, ask these questions.

Guiding Questions

AL **How can you describe what happens to the total mass in a chemical reaction using the words *reactants* and *products*?**	*The total mass of the reactants is equal to the total mass of the products in a chemical reaction.*
OL **What happens to the total mass of the reactants in a chemical reaction?**	*In a reaction, total mass is not lost or gained. Instead, it is conserved. Therefore, the total mass of the products equals the total mass of the reactants.*
BL **Why is the experiment in Figure 4 done with a closed container?**	*One of the products is carbon dioxide, a gas. If a chemical reaction produces a gas, you must contain the gas to measure it properly.*

Word Origin

product

Ask: **How does the origin of the word help to explain the use of the word product at a factory?** *Products, like clothes, are assembled at factories from various fabrics, such as wool and cotton.*

Ask: **How does the origin of the word help to explain the use of the word product as the result of the chemical equation?** *A product is what is produced when bonds of reactants break and form new bonds.*

Atoms are conserved.

Remind students that all atoms have mass. Review how balances measure the mass of matter. Explain that finding the mass of a gas is more difficult than finding the mass of a solid or liquid. Explain that the experiment in **Figure 4** used a closed container to contain the gas.

Guiding Questions

AL **What does conserve mean?**	*Possible answers: don't change, retain, stay the same*
OL **How do molecules rearrange in a chemical formula?**	*The bonds between reactant atoms break, rearrange, and form new bonds.*
BL **How would you write the chemical formula for the reaction in Figure 4?**	$NaHCO_3 + HC_2H_3O_2 \rightarrow NaC_2H_3O_2 + H_2O + CO_2$

Differentiated Instruction

AL **Find the Reactants** Hand out index cards. Ask students to review the chemical equations shown in the lesson to this point. On the front of the card have them write the formula and draw a representation of the products of those equations. On the flip side ask them to represent the reactants using a diagram of elements like the one in **Figure 4**.

BL **Diatomic Molecules** Have student work in pairs. Ask them to create a presentation on the seven diatomic molecules. It should explain the following questions: *What is a diatomic molecule? What are the elements commonly found as diatomic molecules? Are any of these elements ever presented as one atom? What happens to diatomic molecules when they are part of an equation? Do their bonds break?*

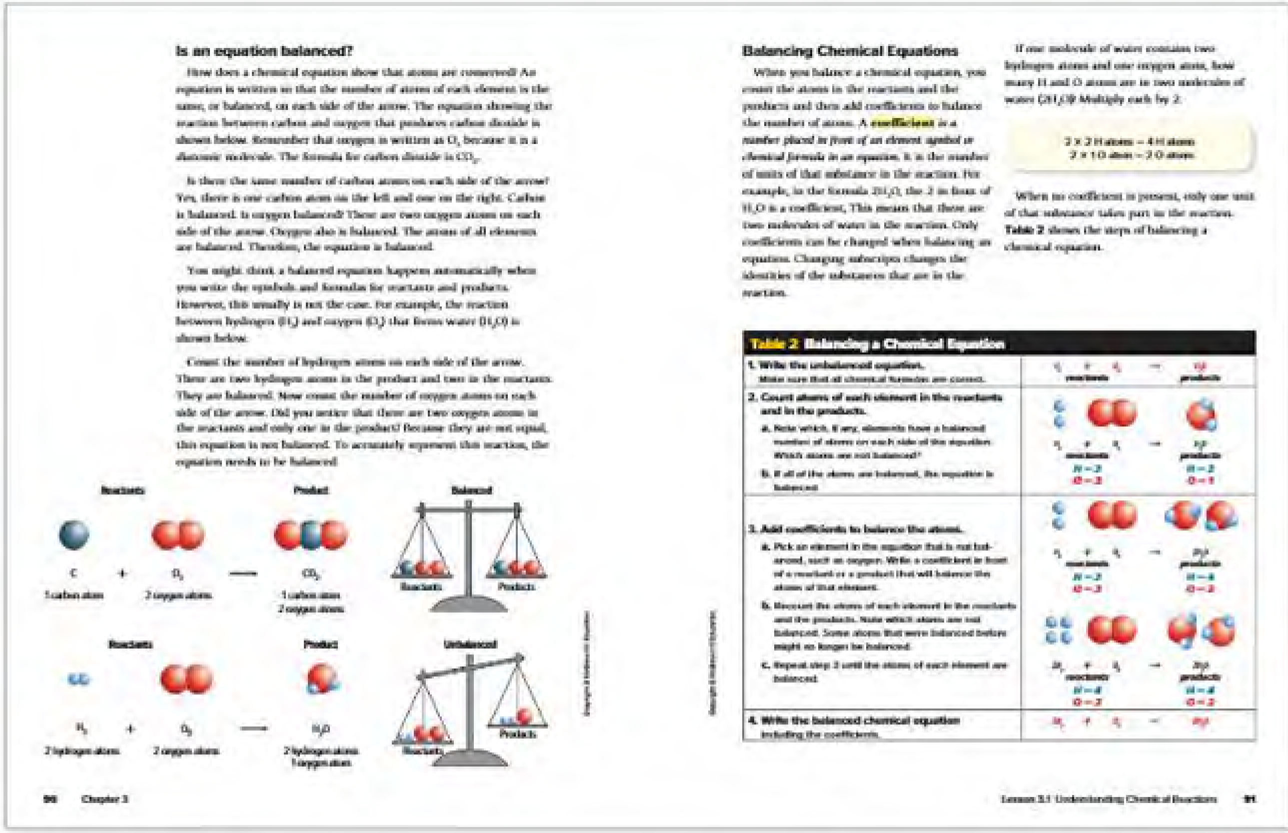
Teacher Toolbox

Teacher Demo

Is it balanced? Play a game with students. Write simple chemical equations on the board. Have students find the number of atoms of each element for the reactants and the product. The first student who can use these numbers to prove if the equation is balanced or not balanced wins!

Fun Fact

Antoine Lavoisier (1743–1794) Lavoisier's list of achievements includes authoring one of the first chemistry textbooks, *Traite Elementaire de Chimien*. In it, he listed and named the 33 elements known at the time. Most of the elements still are recognized today. Lavoisier, sometimes called the father of modern chemistry, also discovered and named oxygen and hydrogen, helped to develop a new system for naming chemicals, and collaborated on the creation of the metric system.



Is an equation balanced?

How does a chemical equation show that atoms are conserved? An equation is written so that the number of atoms of each element is the same, or balanced, on each side of the arrow. The equation showing the reaction between carbon and oxygen that produces carbon dioxide is shown below. Remember that oxygen is written as O_2 because it is a diatomic molecule. The formula for carbon dioxide is CO_2.

Is there the same number of carbon atoms on each side of the arrow? Yes, there is one carbon atom on the left and one on the right. Carbon is balanced. Is oxygen balanced? There are two oxygen atoms on each side of the arrow. Oxygen also is balanced. The atoms of all elements are balanced. Therefore, the equation is balanced.

You might think a balanced equation happens automatically when you write the symbols and formulas for reactants and products. However, this usually is not the case. For example, the reaction between hydrogen (H_2) and oxygen (O_2) that forms water (H_2O) is shown below.

Count the number of hydrogen atoms on each side of the arrow. There are two hydrogen atoms in the product and two in the reactants. They are balanced. Now count the number of oxygen atoms on each side of the arrow. Did you notice that there are two oxygen atoms in the reactants and only one in the product? Because they are not equal, this equation is not balanced. To accurately represent this reaction, the equation needs to be balanced.

Balancing Chemical Equations

When you balance a chemical equation, you count the atoms in the reactants and the products and then add coefficients to balance the number of atoms. A **coefficient** is a *number placed in front of an element symbol or chemical formula in an equation.* It is the number of units of that substance in the reaction. For example, in the formula $2H_2O$, the 2 in front of H_2O is a coefficient. This means that there are two molecules of water in the reaction. Only coefficients can be changed when balancing an equation. Changing subscripts changes the identities of the substances that are in the reaction.

If one molecule of water contains two hydrogen atoms and one oxygen atom, how many H and O atoms are in two molecules of water ($2H_2O$)? Multiply each by 2.

2 × 2 H atoms = 4 H atoms
2 × 1 O atom = 2 O atoms

When no coefficient is present, only one unit of that substance takes part in the reaction. **Table 2** shows the steps of balancing a chemical equation.

Table 2 Balancing a Chemical Equation

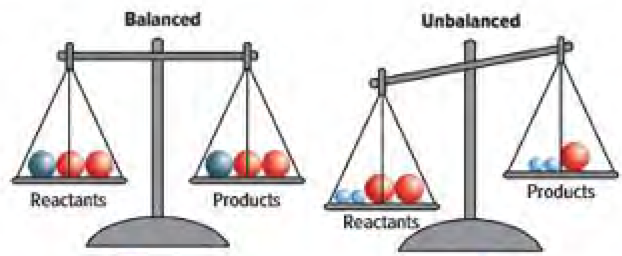
1. Write the unbalanced equation. Make sure that all chemical formulas are correct.	H_2 + O_2 → H_2O (reactants, products)
2. Count atoms of each element in the reactants and in the products. a. Note which, if any, elements have a balanced number of atoms on each side of the equation. Which atoms are not balanced? b. If all of the atoms are balanced, the equation is balanced.	H_2 + O_2 → H_2O; reactants H = 2, O = 2; products H = 2, O = 1
3. Add coefficients to balance the atoms. a. Pick an element in the equation that is not balanced, such as oxygen. Write a coefficient in front of a reactant or a product that will balance the atoms of that element. b. Recount the atoms of each element in the reactants and the products. Note which atoms are not balanced. Some atoms that were balanced before might no longer be balanced. c. Repeat step 3 until the atoms of each element are balanced.	H_2 + O_2 → $2H_2O$; reactants H = 2, O = 2; products H = 4, O = 2. $2H_2$ + O_2 → $2H_2O$; reactants H = 4, O = 2; products H = 4, O = 2
4. Write the balanced chemical equation including the coefficients.	$2H_2$ + O_2 → $2H_2O$

Is an equation balanced?

Use the figure in this section to review with students the connections among concepts covered to this point in this lesson. Chemical reactions break bonds and form new ones. However, a chemical reaction does not create or destroy atoms. Therefore, the mass of reactants is the same as the mass of products. This helps to explain the balance of a chemical equation.

Guiding Questions

AL	**What does it mean when a scale is balanced?**	*The same amount of mass is on both sides of the scale.*
OL	**How do you know a chemical equation is balanced?**	*A chemical equation is balanced when it contains the same number of atoms of each element on each side of the equation.*
BL	**Why is the second equation on this page unbalanced?**	*The number of oxygen atoms is not the same on both sides of the equation.*



Ask: How do you know this scale is balanced?
The two sides are at the same height and the same number of atoms is on each side.

Ask: How do you know this scale is unbalanced?
The left side is lower than the right side, showing the left side has more mass because it has an extra atom.

Visual Literacy: Balance

Use the images on the page to help students visualize balanced equations. Point out that these images are models for balancing chemical equations. A balance could not be used to mass atoms or molecules because they are too small, and it can't measure a gas because it would not stay on the balance pan.

Ask: Which diatomic molecules are shown on this page? *oxygen and hydrogen*

Balancing Chemical Equations

Unbalanced equations misrepresent chemical reactions. Discuss with students how, in the real world, a chemical reaction automatically balances the reactants and products. In order to represent the reaction as a mathematical equation correctly, the equation must be balanced.

Guiding Questions

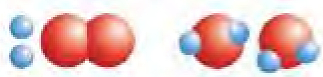
AL How can you change an equation to balance it?	*You can add coefficients to balance an equation.*
OL What is the coefficient of 3O2? What does it tell you?	*The coefficient, 3, means that there are 3 diatomic oxygen molecules present.*
BL When you add a coefficient in front of an atom, what does this mean for the substance?	*When you add a coefficient in front of an atom, it means that more atoms of that substance are present.*

Visual Literacy: Balancing a Chemical Equation

Students who have difficulty making inferences from graphics and tables may struggle to understand how the steps for balancing an equation. Use these questions to help students analyze the diagram.

Ask: How do you know when an element is not balanced in an equation? *The number of atoms of that element is not the same in reactants and products.*

Ask: In row 2 above, which element is not balanced? *In row 2, the oxygen is not balanced.*



$H_2 + O_2 \rightarrow 2H_2O$

reactants | products

H = 2 | H = 4
O = 2 | O = 2

$2H_2 + O_2$ | $2H_2O$

reactants | products

H = 4 | H = 4
O = 2 | O = 2

Ask: In the top of row 3, which element is not balanced? *In row 2, oxygen is not balanced. In the top equation of row 3, the hydrogen is not balanced. Why is 2 the coefficient of the product? in order to have 2 oxygen atoms in the product*

Ask: In the bottom equation of row 3, why do you think 2 was chosen for the coefficient of the hydrogen atoms in the reactants? *In order for there to be a total of 4 hydrogen atoms in the reactants, there needed to be 2 hydrogen molecules.*

Ask: How can you tell how many atoms are in a chemical compound? *First, determine the elements in the compound. Then count the number of atoms of each element. The subscript indicates the number of atoms.*

Teacher Toolbox

Technology Activity

Using the Internet There are many Web sites that will balance equations for you. Have students research some of these sites. Students should use them to balance some of the equations that are in this lesson. Discuss why these Web sites might be helpful for more complicated reactions. Remember to monitor Internet activities carefully.

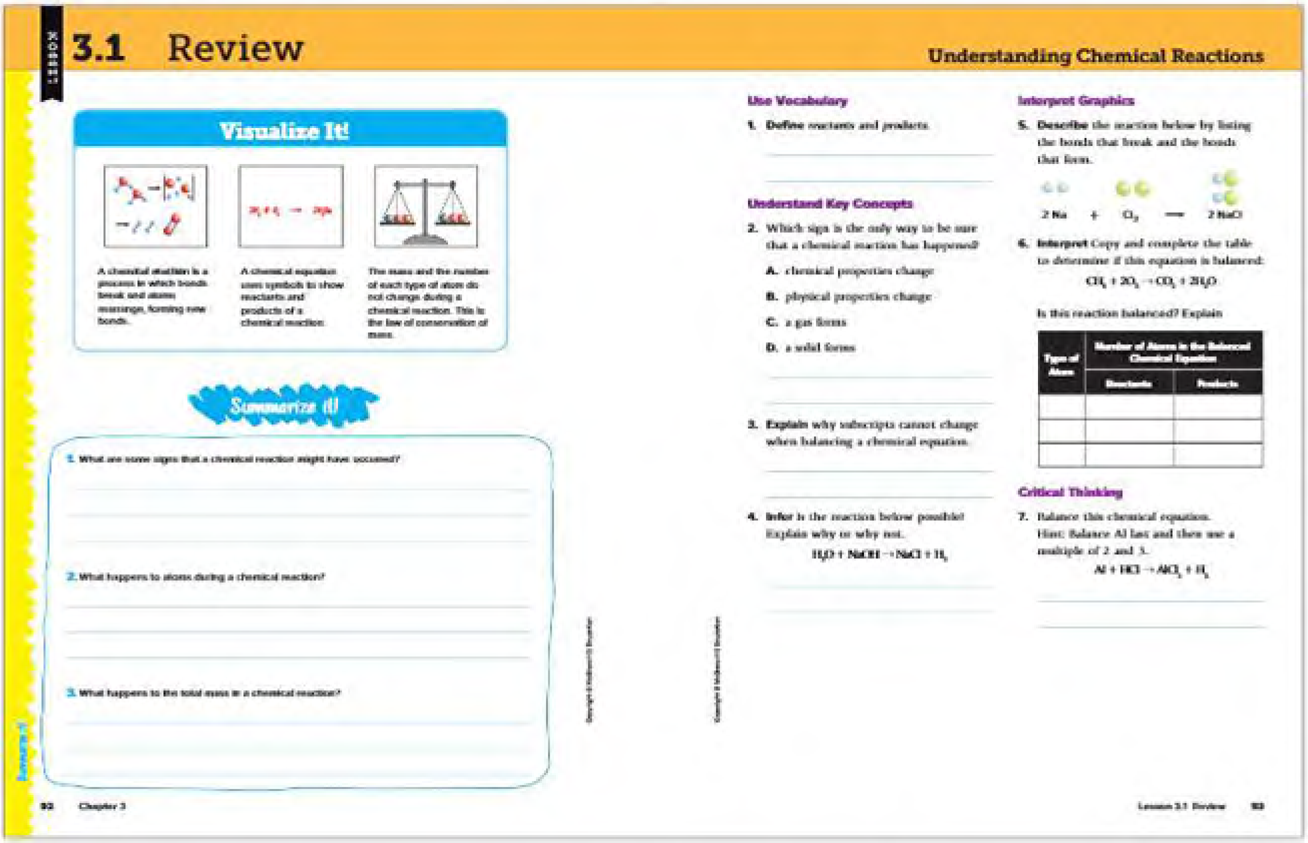
Reading Strategy

Draw a Diagram Have students represent the steps for balancing chemical equations in Table 2 as a flowchart. Be sure students have arrows pointing from Step 3 back to itself to double check that all elements are balanced.

Teacher Demo

Balancing an Equation Review the steps for balancing the equation given in the table using manipulatives. Cut out circles of blue paper to represent the oxygen atoms and circles of red paper to represent the hydrogen atoms. Review each step in balancing the equation, showing the circles to represent the atoms.

OL On Level AL Approaching Level BL Beyond Level



3.1 Review

Understanding Chemical Reactions

Visualize It!

A chemical reaction is a process in which bonds break and atoms rearrange, forming new bonds.

A chemical equation uses symbols to show reactants and products of a chemical reaction.

The mass and the number of each type of atom do not change during a chemical reaction. This is the law of conservation of mass.

Summarize It!

1. What are some signs that a chemical reaction might have occurred?

2. What happens to atoms during a chemical reaction?

3. What happens to the total mass in a chemical reaction?

Use Vocabulary

1. **Define** reactants and products.

Understand Key Concepts

2. Which sign is the only way to be sure that a chemical reaction has happened?
   A. chemical properties change
   B. physical properties change
   C. a gas forms
   D. a solid forms

3. **Explain** why subscripts cannot change when balancing a chemical equation.

4. **Infer** Is the reaction below possible? Explain why or why not.
   $H_2O + NaOH \rightarrow NaCl + H_2$

Interpret Graphics

5. **Describe** the reaction below by listing the bonds that break and the bonds that form.
   2 Na + Cl_2 → 2 NaCl

6. **Interpret** Copy and complete the table to determine if this equation is balanced:
   $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

   Is this reaction balanced? Explain

Type of Atom	Number of Atoms in the Balanced Chemical Equation	
	Reactants	Products

Critical Thinking

7. Balance this chemical equation. Hint: Balance Al last and then use a multiple of 2 and 3.
   $Al + HCl \rightarrow AlCl_3 + H_2$

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Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Ask: To which Key Concept does each image relate?**

Summarize It!

The information needed to complete this graphic organizer can be found in the following sections:

- Signs of a Chemical Reaction
- What happens in a chemical reaction?
- Chemical Equations
- Conservation of Mass

Use Vocabulary

1. Reactants are substances that exist at the start of a chemical reaction. Products are produced by a chemical reaction.

Understand Key Concepts

2. A. chemical properties change.

3. Changing the subscripts changes the substances that react and are produced in a reaction. The new formulas no longer accurately represent the substances that participate in the reaction.

4. The reaction is not possible because oxygen is in a reactant but not shown in a product. Chlorine is shown in a product but not in a reactant.

Interpret Graphics

5. In the reaction, bonds break between chlorine atoms and bonds form between sodium and chlorine atoms.

6. Yes, the equation is balanced. The number of atoms is equal on both sides of the equation.

Type of Atom	Number of Atoms in a Balanced Chemical	
	Reactants	Products
Carbon (C)	1	1
Hydrogen (H)	4	4
Oxygen (O)	4	4

Critical Thinking

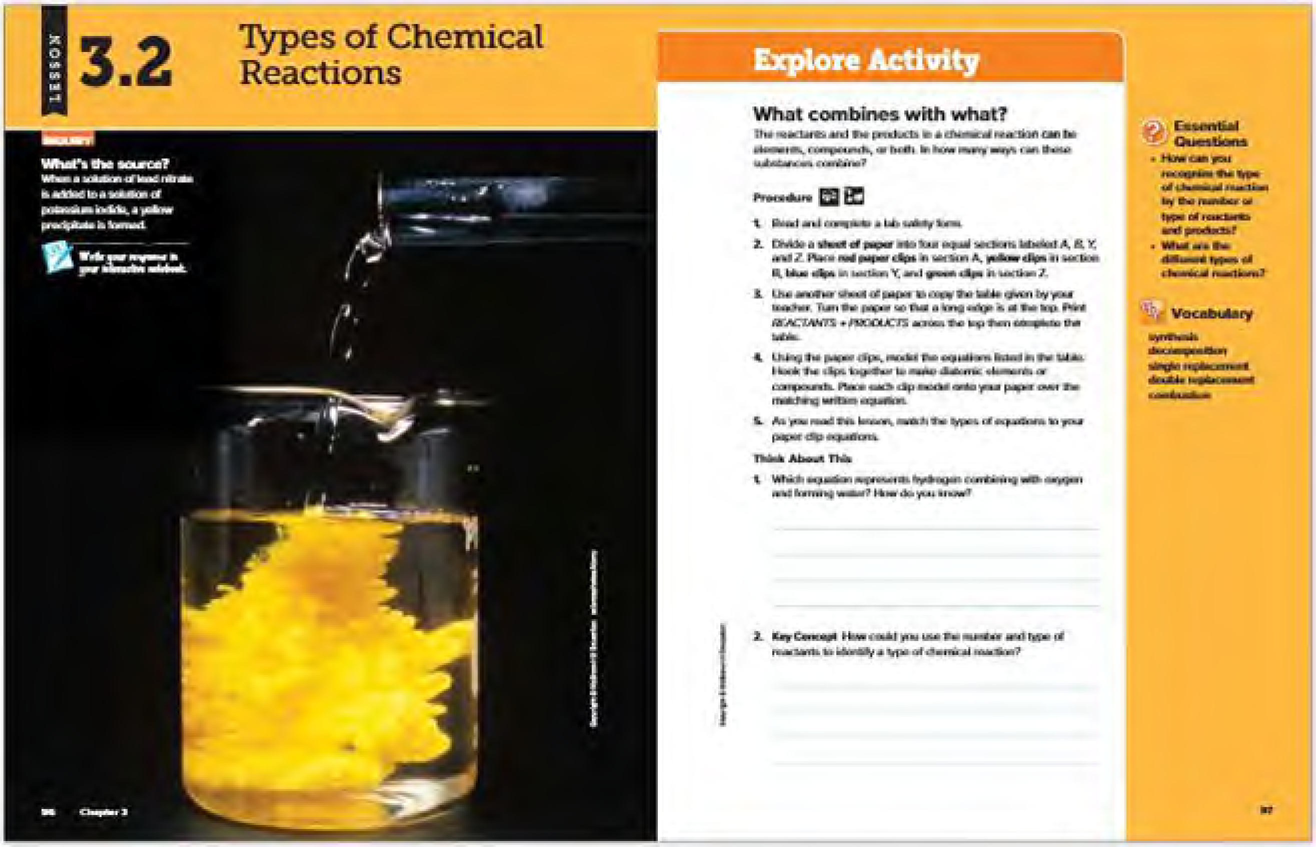
7. The multiple of two and three is 6. Place a 6 in front of HCl. Place a 2 in front of AlCl3 to balance the chlorine. Place a 3 in front of H2 to balance the H2. Finally, place a 2 in front of the Al to balance aluminum.

$Al + HCl \rightarrow AlCl_3 + H_2$
$2Al + 6HCl \rightarrow 2AlCl_3 + 3H_2$

Teacher Notes

Teacher Notes

Teacher Notes



LESSON 3.2 Types of Chemical Reactions

INQUIRY

What's the source?
When a solution of lead nitrate is added to a solution of potassium iodide, a yellow precipitate is formed.

Write your response in your interactive notebook.

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Explore Activity

What combines with what?
The reactants and the products in a chemical reaction can be elements, compounds, or both. In how many ways can these substances combine?

Procedure

1. Read and complete a lab safety form.
2. Divide a **sheet of paper** into four equal sections labeled A, B, Y, and Z. Place **red paper clips** in section A, **yellow clips** in section B, **blue clips** in section Y, and **green clips** in section Z.
3. Use another sheet of paper to copy the table given by your teacher. Turn the paper so that a long edge is at the top. Print *REACTANTS → PRODUCTS* across the top then complete the table.
4. Using the paper clips, model the equations listed in the table. Hook the clips together to make diatomic elements or compounds. Place each clip model onto your paper over the matching written equation.
5. As you read this lesson, match the types of equations to your paper clip equations.

Think About This

1. Which equation represents hydrogen combining with oxygen and forming water? How do you know?
2. **Key Concept** How could you use the number and type of reactants to identify a type of chemical reaction?

Essential Questions
- How can you recognize the type of chemical reaction by the number or type of reactants and products?
- What are the different types of chemical reactions?

Vocabulary
synthesis
decomposition
single replacement
double replacement
combustion

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INQUIRY

About the Photo The reaction shown between lead nitrate and potassium iodide is a double replacement reaction. The two negative ions, NO3– and I–, switch metals and form new substances.

Guiding Questions

AL **What color are the liquids in the picture? What color are the solids?**	*The liquids are clear; the solids are clear (the beaker) and yellow (lead iodide).*
OL **What parts of the reactants combined to form lead iodide?**	*The lead from the lead nitrate and the iodide from the potassium iodide.*
BL **The equation for this reaction is Pb(NO3)2 (aq) + 2KI (aq) → PbI2(s) + ?KNO3 (aq). What number is in the product to balance the equation?**	*Two*

LAB Manager

Labs can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Combustion v. Decomposition

1. Write combustion and decomposition on the board. Add spaces between the words' syllables.
2. Ask a series of questions that link these two words to others students know.

   Ask: What other words do you know that start with *comb?* *combine, combustible*

   Ask: What does compose mean? *to make something*

   Ask: What is the meaning of the prefix *de?* *opposite of; reverse*

   Ask: What other words do you know that start with *de?* *detour, decode, defrost*

3. Have students brainstorm definitions for combustion and decomposition. Encourage students to think about where they may have heard these words to help them come up with ideas. Instruct them to look at the lesson title and the lesson's key concept questions as clues.

4. Ask students to decide how the meanings of these words are alike and how they are different.
5. Create a Venn diagram using the compare and contrast students' ideas. As they read the lesson, ask them to consider how the other vocabulary words might relate to combustion and decomposition.

Explore Activity

What combines with what?

Prep: *5 min* **Class:** *15 min*

Purpose
To model composition, decomposition, and single and double replacement reactions.

Materials
Student: 2 sheets of paper, a pencil, and red, yellow, blue, and green paper clips (15 of each)

Before You Begin
Discuss examples of reactions in Lesson 1. Explain that reactants can be two elements, a compound, an element and a compound, or two compounds. Students will use paperclips to model how reactants combine.

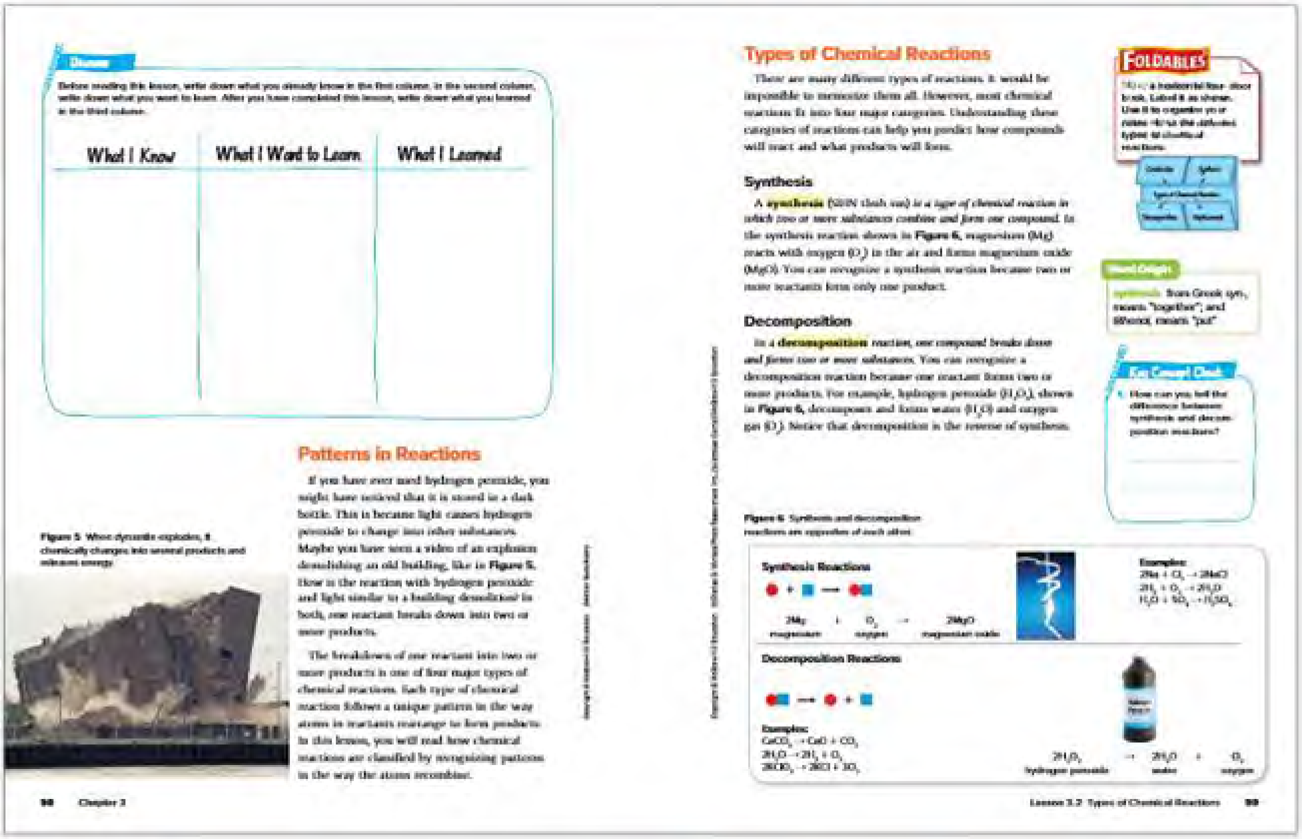
Guide the Investigation
Write this equation on the board: H2 + Cl2 → 2HCl. Explain that the reactants are elements that are diatomic molecules. Use paper clips for reactants and products and demonstrate the equation. Tell students to write a plus sign and arrow in their equations.

Think About This

Students may not know the answers to all questions. Encourage them to hypothesize.

1. Equation 3 represents this reaction. Students should know that hydrogen and oxygen are elements that are diatomic molecules that combine and form a compound, water.
2. **Key Concept** Each type of reaction begins with something different. For example, 1 begins with one compound; 2 and 3 begin with two elements; 4 and 5 begin with an element and a compound; 6 begins with two compounds.

Teacher Notes



Before reading this lesson, write down what you already know in the first column. In the second column, write down what you want to learn. After you have completed this lesson, write down what you learned in the third column.

What I Know	What I Want to Learn	What I Learned

Figure 5 When dynamite explodes, it chemically changes into several products and releases energy.

Patterns in Reactions

If you have ever used hydrogen peroxide, you might have noticed that it is stored in a dark bottle. This is because light causes hydrogen peroxide to change into other substances. Maybe you have seen a video of an explosion demolishing an old building, like in **Figure 5**. How is the reaction with hydrogen peroxide and light similar to a building demolition? In both, one reactant breaks down into two or more products.

The breakdown of one reactant into two or more products is one of four major types of chemical reactions. Each type of chemical reaction follows a unique pattern in the way atoms in reactants rearrange to form products. In this lesson, you will read how chemical reactions are classified by recognizing patterns in the way the atoms recombine.

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Types of Chemical Reactions

There are many different types of reactions. It would be impossible to memorize them all. However, most chemical reactions fit into four major categories. Understanding these categories of reactions can help you predict how compounds will react and what products will form.

Synthesis

A **synthesis** (SIHN thuh sus) *is a type of chemical reaction in which two or more substances combine and form one compound.* In the synthesis reaction shown in **Figure 6**, magnesium (Mg) reacts with oxygen (O_2) in the air and forms magnesium oxide (MgO). You can recognize a synthesis reaction because two or more reactants form only one product.

Decomposition

In a **decomposition** reaction, *one compound breaks down and forms two or more substances.* You can recognize a decomposition reaction because one reactant forms two or more products. For example, hydrogen peroxide (H_2O_2), shown in **Figure 6**, decomposes and forms water (H_2O) and oxygen gas (O_2). Notice that decomposition is the reverse of synthesis.

Figure 6 Synthesis and decomposition reactions are opposites of each other.

Lesson 3.2 Types of Chemical Reactions 99

Patterns in Reactions

Review the properties of chemical reactions in **Lesson 1** and in **Figure 1**. List six signs that a chemical reaction may have occurred. Remind students that these signs result when chemical bonds break and new bonds form. In this lesson, students will classify chemical reactions into one of four categories by analyzing how bonds break and reform.

Guiding Questions

AL **How many types of chemical reactions are there?**	*There are four types of chemical reactions.*
OL **Will new atoms form when a reactant breaks down into two or more products? Why or why not?**	*No; the type and number of atoms will remain the same. The number and types of atoms stay the same in chemical reactions.*
BL **What causes hydrogen peroxide to react when it is not kept in a dark bottle?**	*The energy in light causes the bonds to break between atoms. New bonds form and produce new substances.*

Types of Chemical Reactions

Discuss the concept of categorizing items with students. Remind students that, so far, reactions simply have been either chemical or a physical. Now students will learn how to classify chemical reactions based on the number of reactants and products, and how the reactants combine or separate.

Synthesis

Review examples of synthesis familiar to students, such as hydrogen and oxygen reacting and forming water, iron and oxygen reacting and forming rust, or sodium and chlorine reacting and forming salt. Point out that in each example includes two reactants and one product.

Guiding Questions

OL **How does the chemical equation $2Mg + O_2 \rightarrow 2MgO$ in Figure 6 show a synthesis reaction?**	*There are two reactants and only one product (more reactants than products).*
BL **Is the reaction in the lesson opener photo a synthesis reaction?**	*Possible answer: No, because two substances, lead nitrate and potassium iodide, react and to form two substances, lead iodide and potassium nitrate.*

Word Origin

synthesis

Ask: How does the word origin help define synthesis in chemistry? *Chemical synthesis can be defined as a reaction that "puts together" elements or compounds.*

Decomposition

Explain that decomposition is the opposite of synthesis. Explain that both break chemical bonds, but in decomposition there are more products than reactants.

Visual Literacy: Synthesis and Decomposition Reactions

Use **Figure 6** to help students visualize the differences between synthesis and decomposition reactions.

Ask: How can you tell the difference between synthesis and decomposition reactions? *In synthesis reactions, two or more reactants react and form a product. In decomposition reactions, one reactant breaks down and two or more products form.*

Ask: Suppose magnesium hydroxide decomposed. How many products would you expect? Why? *In decomposition, there are more products than reactants. At least two products should form.*

Ask: Which reaction in Figure 6 has more reactants than products? ***The synthesis reaction.*** **How many reactants are there?** *2* **How many products are there?** *1*

Ask: In the decomposition reaction, what substance does the paired red and blue icons represent? ***hydrogen peroxide***

Differentiated Instruction

AL Opposites Have student pairs create a list of actions that are opposites, such as heating something up or cooling it down, turning on a light or turning it off, and so on. Discuss how students know that the actions are opposites. Relate this list to synthesis and decomposition reactions. Have students write a list of statements that include the characteristics of synthesis and decomposition that show that they are opposite reactions.

BL Name that Reaction After completing this lesson, organize students into five groups. Have each group research one of the chemical reactions listed below. Students should find the chemical equation for the reaction, describe what happens to the substances in the reaction, and classify the reaction as synthesis, decomposition, replacement, or combustion. Have students present their findings to the class.

Fire burning, zinc plating of tools, silver tarnishing
Change in carbonic acid in soda
Changes in hydrogen peroxide when exposed to sunlight

Teacher Toolbox

Teacher Demo

Synthesis or Decomposition? Write a series of equations on the board:

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
$2NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$
$2Mg + O_2 \rightarrow 2MgO$
$H_2 + Cl_2 \rightarrow 2HCl$

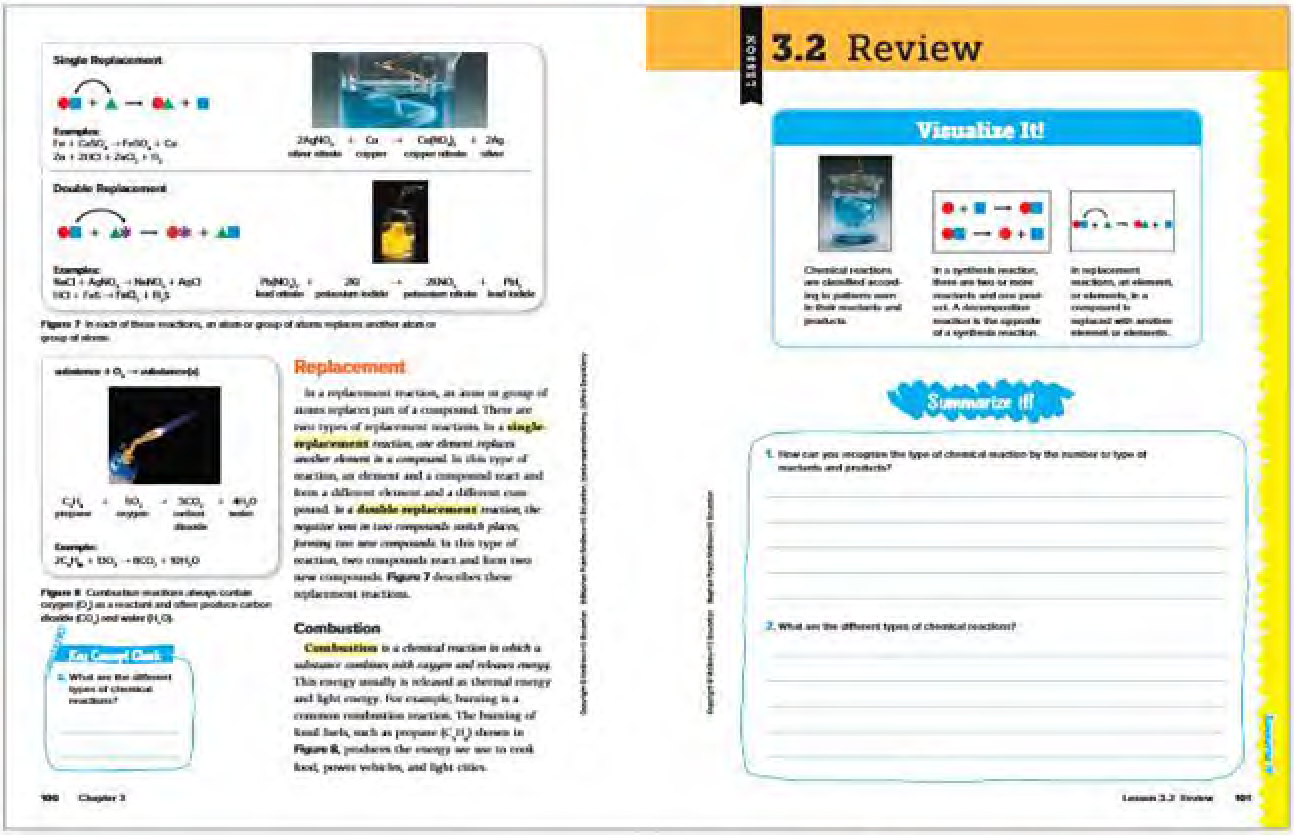
Have students identify which are synthesis equations and which are decomposition equations.

Real-World Science

Baking Soda Baking soda is a leavening agent in many recipes. When heated to more than 50°C, it decomposes and forms carbon dioxide, water, and sodium carbonate. The carbon dioxide forms small bubbles in the batter, causing the baked good to rise. The decomposition reaction is:

$$2NaHCO_3 \rightarrow Na2CO_3 + H_2O + CO_2$$

OL On Level AL Approaching Level BL Beyond Level



Replacement

Have students trace arrows in **Figure 7** to show how components of reactants rearrange and form products. The number of reactants equals the number of products.

Ask: If you represent reactants in a double replacement reaction as AB + CD, how would you represent the products? How do you know? *In a double replacement reaction, both reactants break apart and components rearrange in products. The products would be AC + BD.*

Combustion

Explain that oxygen always is present in a combustion reaction and that energy always is released. Reactions that include oxygen but do not release thermal energy are not combustion reactions.

Guiding Questions

AL **What element is necessary for a combustion reaction?**	*Oxygen is necessary for a combustion reaction.*
OL **What are the different types of chemical reactions?**	*The different types of reactions are synthesis, decomposition, replacement, and combustion.*

Visual Literacy: Replacement Reactions

Use the questions below to help students analyze **Figure 7** and to assess their understanding of replacement reactions.

Ask: Which element or compound moves in this reaction? Where does it move to? *The compound SO_4 moves from copper to iron.*

Ask: Which elements or compounds switch places in this reaction? *Cl and NO_3 switch places.*

$Fe + CuSO_4 \longrightarrow FeSO_4 + Cu$
$Zn + 2HCl + ZnCl_2 + H_2$

$NaCl + AgNO_3 \longrightarrow NaNO_3 + AgCl$
$HCl + FeS \longrightarrow FeCl_2 + H_2S$

Ask: In this reaction the chlorine moves from the hydrogen to the Zinc. What happens to the coefficient in front of the HCl? *The coefficient shows two HCl molecules. In the product, a coefficient is not needed because, as elements, chlorine and hydrogen are diatomic molecules.*

Ask: Which elements or compounds switch places in this reaction? *Hydrogen and iron switch places.*

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Ask:** **Which Key Concept does each image relate to?**

Summarize it!

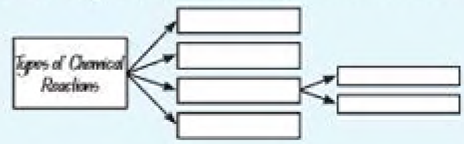
The information needed to complete this graphic organizer can be found in the following sections:

- Patterns in Reactions
- Types of Chemical Reactions

Teacher Toolbox

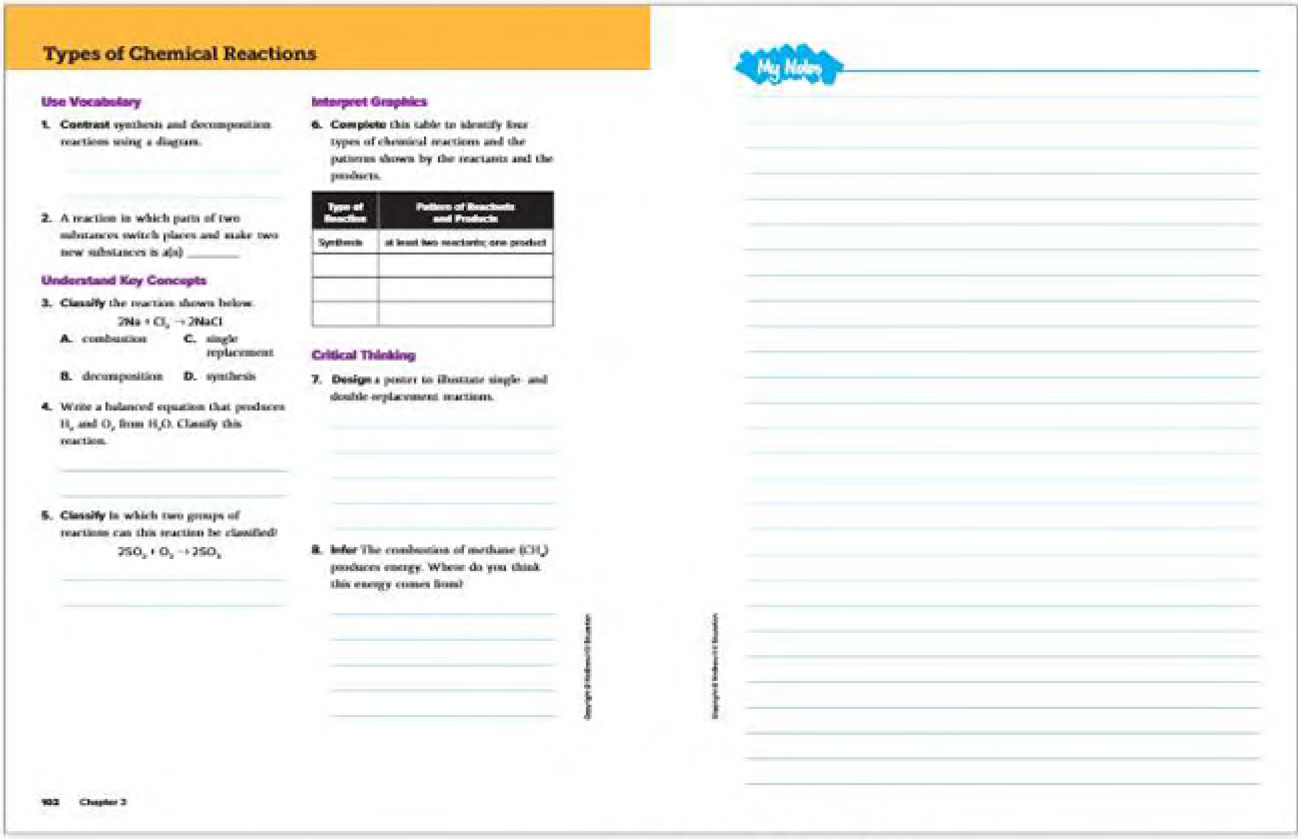
Teacher Demo

Reaction Diagram Draw a diagram on the board similar to the one shown below. Have students fill in the blocks with the different types of chemical reactions in this lesson.



Fun Fact

Spontaneous Combustion Items that catch on fire without an external source of thermal energy are said to have "spontaneously combusted." When large piles of flammable materials, such as coal, hay, or oily rags, are stored in places without air circulation, spontaneous combustion can occur. Exothermic chemical reactions that occur in the middle of the pile release thermal energy that is trapped inside the pile. This trapped thermal energy increases the reaction rate, releasing more and more thermal energy. Eventually, the materials become hot enough to burst into flames.



Types of Chemical Reactions

Use Vocabulary

1. **Contrast** synthesis and decomposition reactions using a diagram.

2. A reaction in which parts of two substances switch places and make two new substances is a(n) ________

Understand Key Concepts

3. **Classify** the reaction shown below.
$2Na + Cl_2 \rightarrow 2NaCl$
A. combustion C. single replacement
B. decomposition D. synthesis

4. Write a balanced equation that produces H_2 and O_2 from H_2O. Classify this reaction.

5. **Classify** In which two groups of reactions can this reaction be classified?
$2SO_2 + O_2 \rightarrow 2SO_3$

Interpret Graphics

6. **Complete** this table to identify four types of chemical reactions and the patterns shown by the reactants and the products.

Type of Reaction	Pattern of Reactants and Products
Synthesis	at least two reactants; one product

Critical Thinking

7. **Design** a poster to illustrate single- and double-replacement reactions.

8. **Infer** The combustion of methane (CH_4) produces energy. Where do you think this energy comes from?

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My Notes

Vocabulary

1. In a synthesis reaction, two or more reactants produce one product. In a decomposition reaction, one reactant produces two or more products. Diagrams should reflect these definitions.
2. double replacement reaction

Understand Key Concepts

3. **D.** synthesis
4. $2H_2O \rightarrow 2H_2 + O_2$; decomposition
5. synthesis; combustion

Interpret Graphics

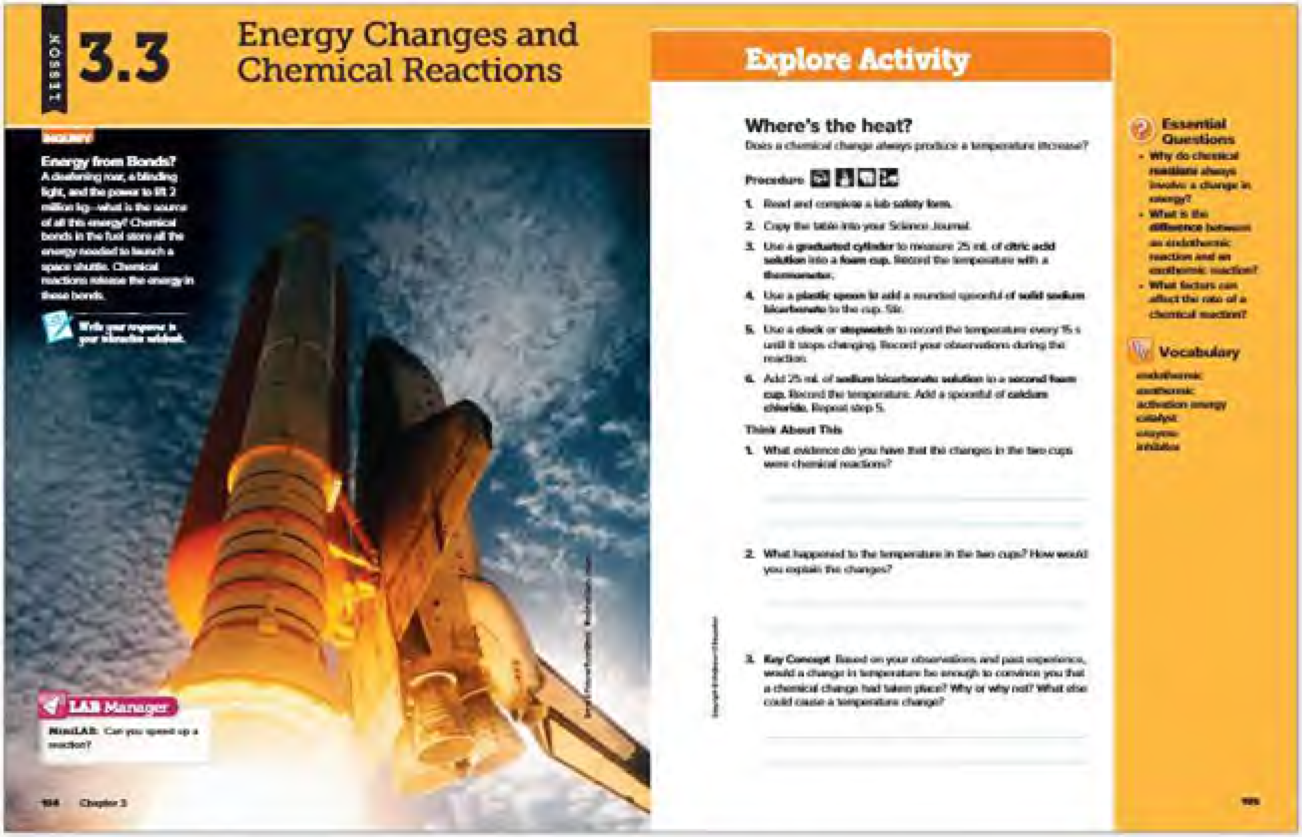
6.

Type of Reaction	Pattern of Reactants and Products
Synthesis	At least two reactants; one product
Decomposition	One reactant; at least two products
Replacement	A reactant(s) breaks apart, and components rearrange and form a product(s)
Combustion	One substance combines with oxygen and releases energy.

Critical Thinking

7. Compare students' answers with **Figure 7.**
8. Students might propose that energy is released when bonds break.

Teacher Notes


LESSON 3.3 Energy Changes and Chemical Reactions

INQUIRY

Energy from Bonds?

LAB Manager

Explore Activity

Where's the heat?

Does a chemical change always produce a temperature increase?

Procedure

1. Read and complete a lab safety form.
2. Copy the table into your Science Journal.
3. Use a **graduated cylinder** to measure 25 mL of **citric acid solution** into a **foam cup**. Record the temperature with a **thermometer**.
4. Use a **plastic spoon** to add a rounded spoonful of **solid sodium bicarbonate** to the cup. Stir.
5. Use a **clock** or **stopwatch** to record the temperature every 15 s until it stops changing. Record your observations during the reaction.
6. Add 25 mL of **sodium bicarbonate solution** to a **second foam cup**. Record the temperature. Add a spoonful of **calcium chloride**. Repeat step 5.

Think About This

1. What evidence do you have that the changes in the two cups were chemical reactions?
2. What happened to the temperature in the two cups? How would you explain the changes?
3. **Key Concept** Based on your observations and past experience, would a change in temperature be enough to convince you that a chemical change had taken place? Why or why not? What else could cause a temperature change?

Essential Questions

- Why do chemical reactions always involve a change in energy?
- What is the difference between an endothermic reaction and an exothermic reaction?
- What factors can affect the rate of a chemical reaction?

Vocabulary

endothermic
exothermic
activation energy
catalyst
enzyme
inhibitor

INQUIRY

About the Photo **Energy from Bonds?** This Delta II rocket is carrying NASA's THEMIS spacecraft, five identical probes that will track colorful atmospheric phenomena near the North Pole. THEMIS, an acronym for Time History of Events and Macroscale Interactions during Substorms, aims to investigate auroral substorms, magnetic energy powered by solar wind that intensifies northern and southern lights.

Guiding Questions

AL **What evidence is there in this photograph that proves a chemical reaction is occurring?**	*Sample answers: The rocket is blasting off with sudden energy. There is fire. There is smoke and light. Increase in heat, release of light, and change in odor are signs of a chemical reaction.*
OL **What are some ways in which the chemical reaction might have been triggered?**	*Students might hypothesize that heat was applied to a substance or that two or more substances were combined.*
BL **What evidence is there that the chemical reaction is releasing heat?**	*Students might mention the smoke, fire, and light that surround the rocket.*

LAB Manager

Labs can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Connect to Prior Knowledge

1. Explain to students that enzymes in the digestive system play a large role in helping break down foods and releasing energy our bodies use.
2. Explain that an enzyme is an example of a catalyst.
3. Have students brainstorm definitions of both enzyme and catalyst.
4. Ask students to write these in their Science Journals and then compare them with the book's definitions.

Explore Activity

Where's the heat?

Prep: 15 min **Class:** 20 min

Purpose
To observe endothermic and exothermic reactions

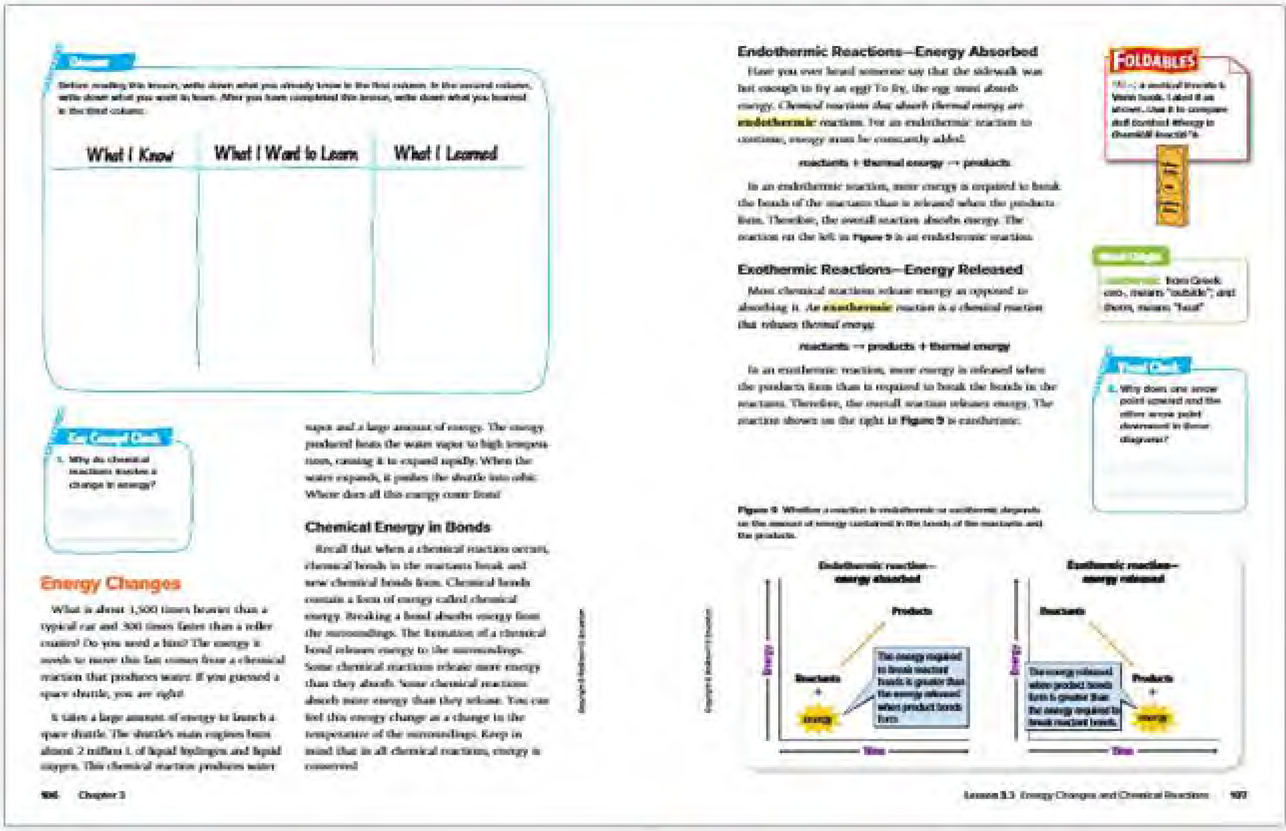
Materials
Student Group (3 or 4): thermometer; 2 foam cups; 2 plastic spoons; a plastic cup containing a spoonful of sodium bicarbonate (baking soda, $NaHCO_3$); a plastic cup containing a spoonful of calcium chloride ($CaCl_2$); 25 mL of a citric acid solution ($H_3C_6H_5O_7$), made from 45 g of citric acid in 250 mL of distilled water; 25 mL of a baking soda solution, made from 17 g of sodium bicarbonate in 250 mL of distilled water, graduated cylinder, clock or stopwatch

Before You Begin
Prepare solutions and pour them into bottles. Lemon juice can replace citric acid solution, but temperature will not drop as much. Solid de-icer can replace calcium chloride, but it must contain some calcium chloride.

Guide the Investigation
- ⚠ Students should wear goggles and gloves.
- Be sure students record the temperature of the liquid after it stops changing. This is the temperature at Time = 0.

Think About This
1. The formation of bubbles and the temperature change indicate that a chemical reaction might have occurred.
2. The temperature in the first cup decreased and the temperature in the second cup increased. Energy was either released or absorbed.
3. **Key Concept** It helps to have another sign of a chemical change, such as a color change or bubbles. Then you have more evidence that a chemical change is happening and not just a change due to the environment's temperature.

Teacher Notes


What I Know | What I Want to Learn | What I Learned

Energy Changes

Chemical Energy in Bonds

Endothermic Reactions—Energy Absorbed

reactants + thermal energy → products

Exothermic Reactions—Energy Released

reactants → products + thermal energy

Energy Changes

Explain that chemical reactions release energy in different ways. In our digestive systems, chemical reactions release energy all day for our bodies. The chemical reactions that launch the space shuttle release large amounts of energy.

Chemical Energy in Bonds

Explain that chemical reactions conserve energy. Write bonds break and bonds form on the board. Have students hypothesize which situation releases energy, and which situation absorbs energy.

Ask: **Why do chemical reactions involve a change in energy? Chemical reactions always involve an energy change because when chemical bonds break or form energy is released or absorbed.**

Endothermic Reactions—Energy Absorbed

Relate an endothermic reaction to a mathematical equation, such as $5 + 3 = 8$. The the amount of energy in the reactants is 5, 3 is the amount of energy added for reaction, and 8 is the amount of energy in the products. Show students that the amount of energy on both sides of the equation is conserved.

Guiding Questions

OL	**How do you know that the amount of energy in reactants plus thermal energy is equal to the amount of energy in the product?**	*In any chemical reaction, energy is conserved. Therefore, in a closed system, the amount of energy in reactants plus thermal energy equals the amount of energy in the products.*
BL	**Do you think a reaction can be a decomposition and endothermic? Why or why not?**	*Yes; decomposition describes how the substances change, but endothermic describes how energy is used.*

Endothermic Reactions—Energy Absorbed

Explain that in endothermic reactions, reactants absorb energy and then form products. Relate exothermic reactions to an equation, such as $8 = 5 + 3$, where 8 is energy in the reactants and 5 and 3 are the energy in the product and the energy released, respectively.

Guiding Questions

AL	**What is the equation that represents an exothermic reaction?**	*reactants → products + energy*
OL	**What is the difference between an endothermic reaction and an exothermic reaction?**	*An endothermic reaction absorbs energy. An exothermic reaction releases energy.*
BL	**Why is photosynthesis endothermic and not exothermic?**	*In photosynthesis, absorbed light energy powers the reaction that produces sugar and oxygen from carbon dioxide and water.*

Word Origin

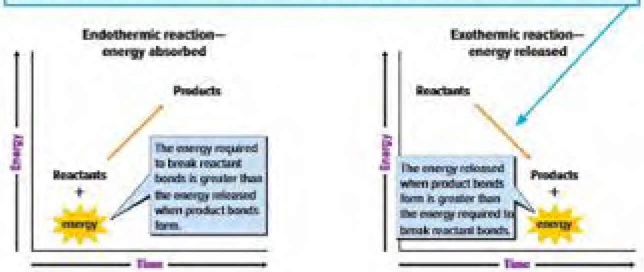
exothermic

Students can distinguish exothermic from endothermic by remembering their prefixes: "exo–" means outside and that "endo–" means inside.

Visual Literacy: Endothermic and Exothermic Reactions

Students may have difficulty seeing these drawings as actual graphs.

Ask: **Why does one arrow point upward and the other arrow point downward in the drawings?** *The upward arrow indicates that energy is absorbed in the reaction. The downward arrow indicates that energy is released in the reaction.*



Differentiated Instruction

AL **Dear Student** Have students work in pairs. Ask them to write a letter to an absent student explaining the difference between endothermic and exothermic reactions. Have pairs share their letters with other groups.

BL **Endo or Exo?** Have students work in pairs and brainstorm different chemical reactions that occur in their everyday lives. They can use Figure 1 from Lesson 1 as a guide. Ask them to hypothesize whether the reactions are endothermic or exothermic. Have students research to find the correct classification.

Teacher Toolbox

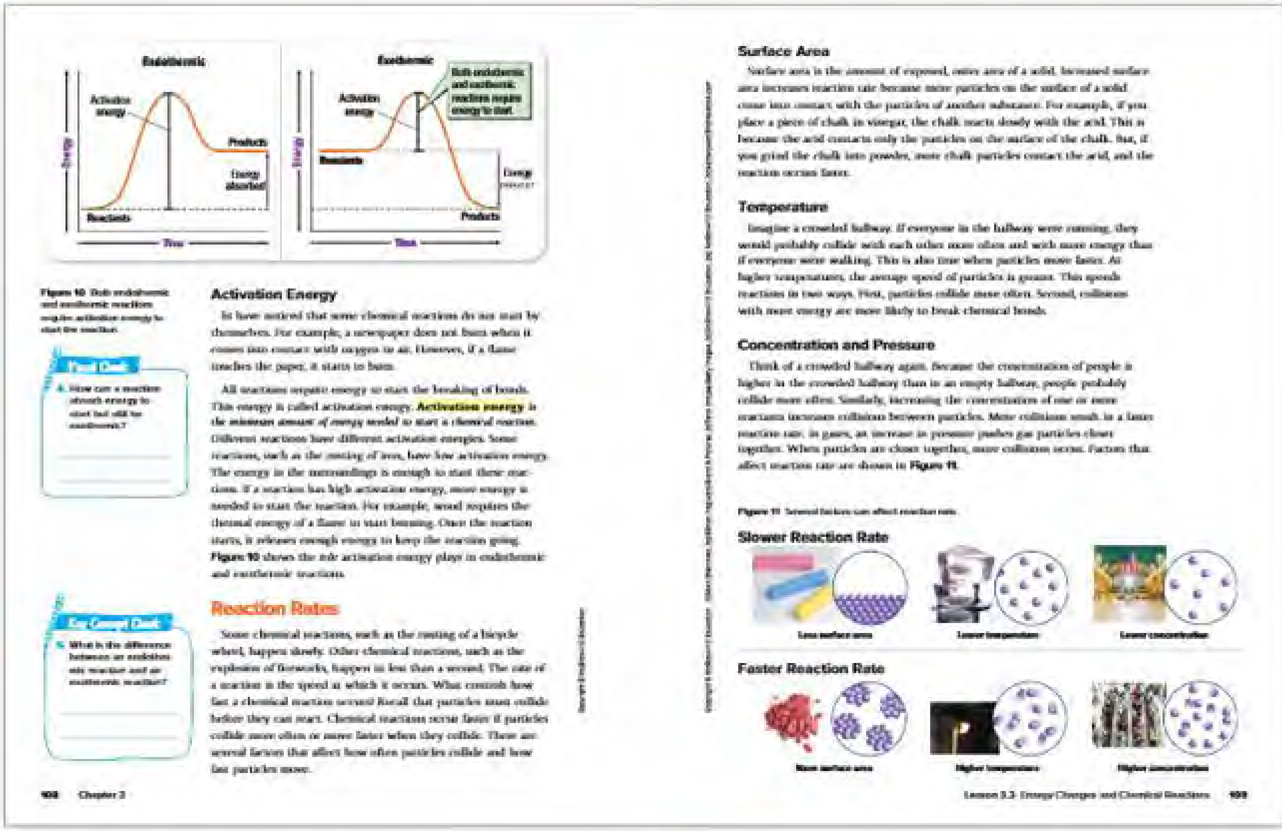
Reading Strategy

Make a List Have students reread the sections on endothermic and exothermic reactions. Students should make a list with facts about endothermic reactions and a list with facts about exothermic reactions. Once students have created their lists they should compare facts.

Real-World Science

Photosynthesis A common endothermic reaction is photosynthesis. During photosynthesis, light energy powers the reaction between carbon dioxide and water that produces glucose and oxygen. Chlorophyll is a catalyst in the reaction. Organisms that absorb energy and produce "food" are called autotrophs, meaning "self-feeders."

OL On Level AL Approaching Level BL Beyond Level



Activation Energy

Students may think that reactions begin spontaneously. Clarify that many reactions need energy, called activation energy, to begin. Have students identify the activation energy in **Figure 10.** Explain that energy can be mechanical, thermal, or electrical. Ask these questions to assess students' understanding.

Guiding Questions

AL **What is activation energy?**	*The minimum amount of energy needed to start a reaction.*
OL **How can a reaction absorb energy to start but still be exothermic?**	*Exothermic reactions need activation energy to start but then release energy.*
BL **Does every reaction have activation energy?**	*Yes. Even if a reaction appears to happen spontaneously, energy is needed to break bonds.*

Reaction Rates

After reviewing the concept of reaction rate, have students brainstorm different factors that may affect reaction rate. Student examples may include temperature of the environment, concentration of components, and relative amounts of reactants. List students' ideas on the board and then review these questions.

Guiding Questions

AL **What is a reaction rate?**	*The reaction rate is how fast a reaction occurs.*
OL **How do mouthparts differ among the shark, the ant, and the moth?**	*Reaction rate increases the more often particles collide and with the intensity of the collision.*
BL **What might you conclude about the particles involved in a slow chemical reaction, such as metal rusting?**	*Particles in the reactants are slow moving and do not often collide.*

Surface Area

Many students confuse surface area and volume. Explain that surface area is the total area on the outside of an object. Demonstrate the change in surface area by crushing chalk to a powder. Discuss the surface area of a large piece of chalk. Break the chalk into two pieces and show that this creates more surfaces. Break each of the pieces into smaller pieces, each time reviewing how and why surface areas increase.

Temperature

Create a diagram for visual learners to help them remember how temperature affects reaction time—an arrow pointing up to the words temperature/reaction time, and an arrow pointing down to temperature/reaction time. Relate this to students' knowledge of how particle collisions affect reaction rates and how a greater particle speed increases collision rates.

Concentration and Pressure

Explain that concentration and pressure mean particles are closer together. If closer together, they are more likely to collide. The more they collide, the more they react. Suppose a bus makes 10 stops, each time picking up 12 students. By the time the bus reaches the last stop, it's packed, and students bump into each other frequently. Concentration can be thought of as the number of students per bus, and pressure can be thought of as the rate at which students bump into each other.

Guiding Questions

AL **What are the four methods for speeding up a chemical reaction?**	*To speed up a chemical reaction, you can increase surface area, heat the particles, increase the concentration of the particles, or increase the pressure of a gas.*
OL **What happens to particles in each method of speeding up a chemical reaction?**	*In each method, the particles move more quickly and collide more frequently and with a greater speed.*
BL **When a reaction occurs in a solution, why does the concentration of reactants change the reaction rate?**	*The greater the concentration of a solution, the greater the number of reactant molecules that collide and collide with greater frequency, thus, a higher reaction rate.*

Math Skills

Use Geometry

Review with students the formula for finding the area of a cube.

Practice

1. *32 cm^2*

Differentiated Instruction

AL **Create Flashcards** Have student work in pairs. Ask them to list different ways that a reaction rate can be changed. Students should create flash cards with a situation occurring on the front, such as "the pressure in a gas is lowered". On the back of the card, they must describe what happens to the rate of the chemical reaction. After students have created 5 to 10 cards, have them join another pair and quiz each other using the cards.

BL **Create a Reaction Graph** Have students work in pairs to research a chemical reaction that requires activation energy to begin. Then ask them to plot them on a graph similar to the one in **Figure 10**, labeling the reactants and the products with the appropriate terms.

Teacher Toolbox

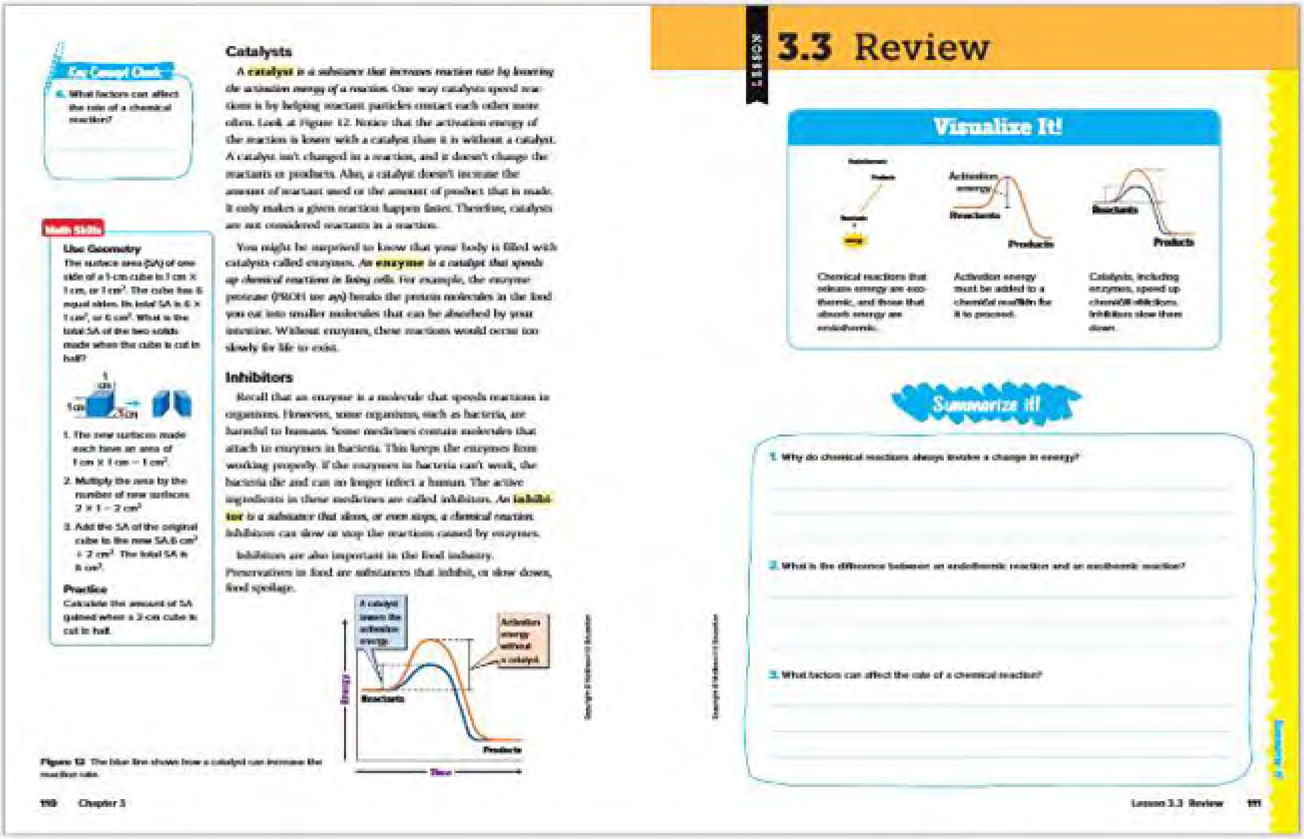
Reading Strategy

Section Heads Have students consider how each section head following **Reaction Rates** relates to it. Ask students to write one sentence to describe the main idea of the reading passage.

Teacher Demo

When Surface Area Doesn't Work Point out that crushing a solid into powder does not always speed up a chemical reaction. What happens when a powder and a gas need to react?

1. Hold up a large piece of chalk. Discuss the surface area of the chalk and how it would be penetrated by a gas.
2. Now crush the chalk and place it in a pile. Again discuss the total surface area of the powdered chalk. Point out that although there is more total surface area, there is less surface area that touches the air. The powered chalk at the bottom of the pile does not touch the air. For this reason there is a less surface area that the gas can penetrate.
3. Discuss how the pile of chalk could be manipulated to allow the gas to better penetrate and speed up the reaction rate.



Catalysts

A catalyst increases the reaction rate of a chemical reaction. Clarify that a catalyst is not a reactant. Create a list on the board of the properties of catalysts. Have students keep the list handy to help them determine whether substances are catalysts.

Inhibitors

Inhibitors are the opposite of catalysts. Students may think that change in temperature is an inhibitor. Explain that an inhibitor is a substance.

Guiding Questions

OL **What factors can affect the rate of a chemical reaction?**	*Surface area, temperature, concentration, pressure, and a catalyst or an inhibitor all can affect the rate of a chemical reaction.*
BL **How do a preservative in food act as an inhibitor?**	*A preservative slows the chemical reaction that causes food to spoil.*

Visual Summary

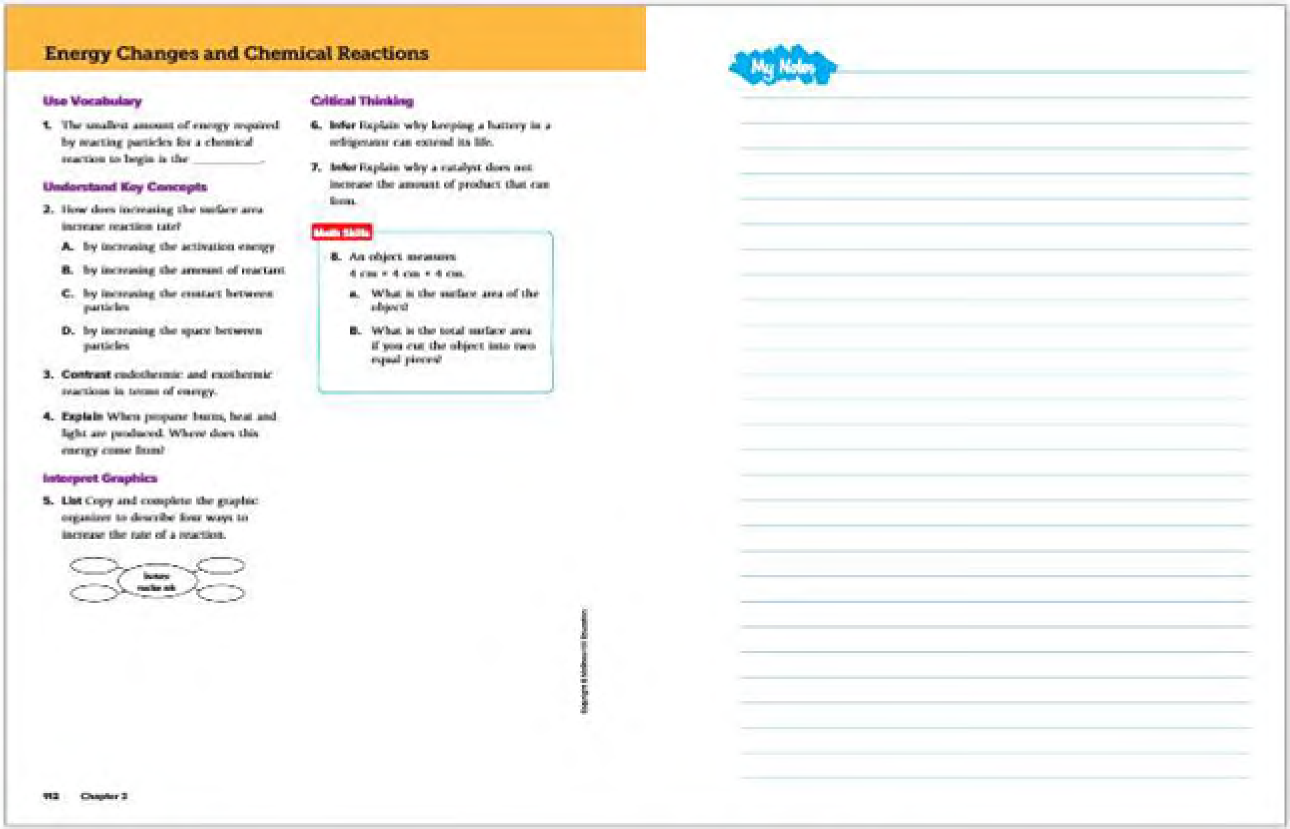
Concepts and terms are easier to remember when they are associated with an image. **Ask: To which Key Concept does each image relate?**

Summarize it!

The information needed to complete this graphic organizer can be found in the following sections:

- Energy Changes
- Reaction Rates

Teacher Notes



Energy Changes and Chemical Reactions

Use Vocabulary

1. The smallest amount of energy required by reacting particles for a chemical reaction to begin is the ___________.

Understand Key Concepts

2. How does increasing the surface area increase reaction rate?
   A. by increasing the activation energy
   B. by increasing the amount of reactant
   C. by increasing the contact between particles
   D. by increasing the space between particles
3. **Contrast** endothermic and exothermic reactions in terms of energy.
4. **Explain** When propane burns, heat and light are produced. Where does this energy come from?

Interpret Graphics

5. **List** Copy and complete the graphic organizer to describe four ways to increase the rate of a reaction.

Critical Thinking

6. **Infer** Explain why keeping a battery in a refrigerator can extend its life.
7. **Infer** Explain why a catalyst does not increase the amount of product that can form.

Math Skills

8. An object measures 4 cm × 4 cm × 4 cm.
   a. What is the surface area of the object?
   b. What is the total surface area if you cut the object into two equal pieces?

My Notes

Use Vocabulary

1. activation energy.

Understand Key Concepts

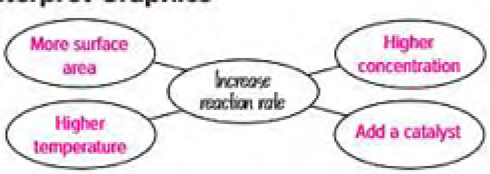
2. C. by increasing the contact between particles.

3. In endothermic reactions, the energy required to break bonds is greater than the energy released when bonds form. In exothermic reactions, the energy required to break bonds is less than the energy released when new bonds form.

4. The energy comes from the bonds of the propane and oxygen (the reactants).

Interpret Graphics

5.



Critical Thinking

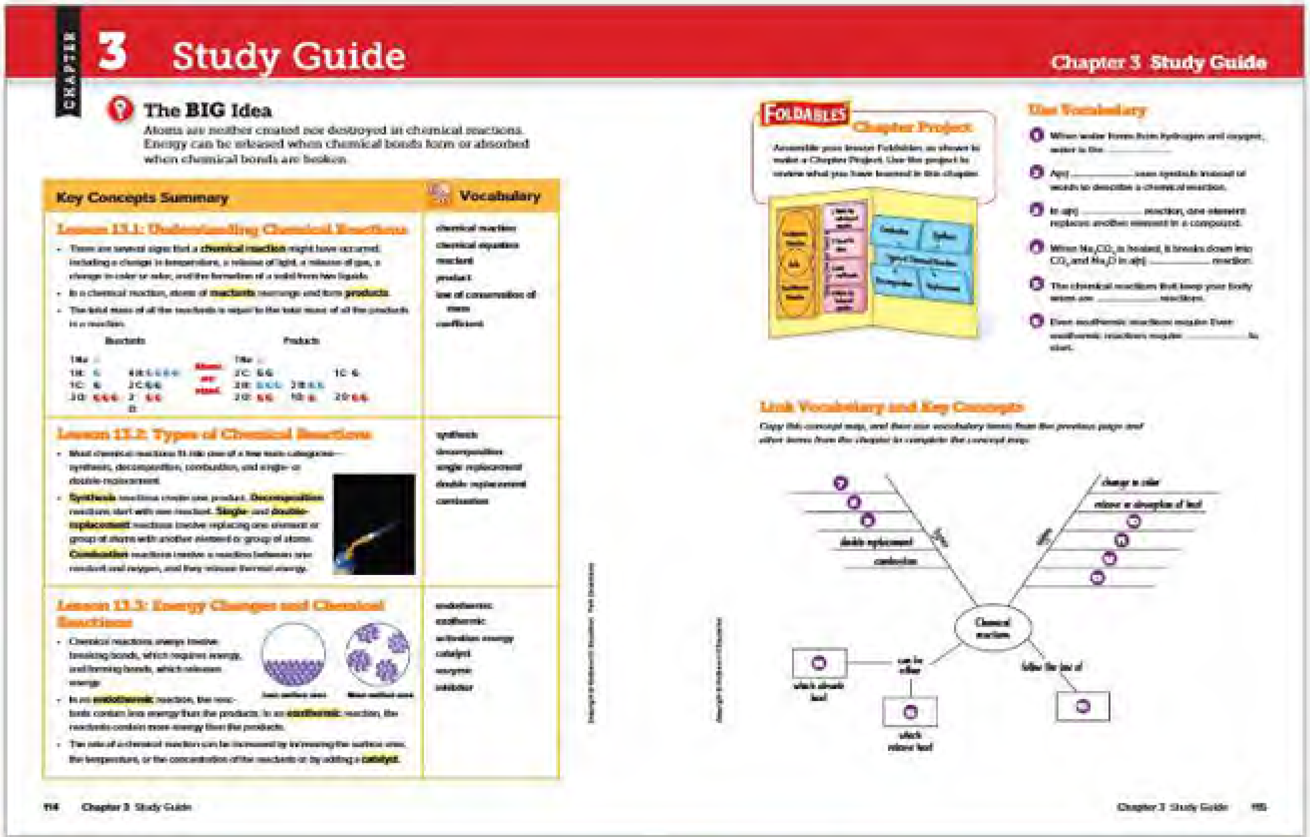
6. The cold temperature slows the rate of reactions inside a battery.

7. A catalyst is not a reactant and doesn't affect the mass of reactants in the reaction. Therefore, the mass of the products does not change.

Math Skills

8. a. 96 cm^2; **b.** 128 cm^2

Teacher Notes



Key Concepts Summary

Study Strategy: Create a Journal

This activity will help students to organize the concepts of the lessons.

1. Form groups of three students each and assign each student a lesson.
2. Have students scan their lessons and write the main ideas in the lesson shown as red titles and then the blue subheads for that title.
3. Students should create one journal entry for each main idea making sure to explain how the blue subheads relate to the main idea.
4. When students have had ample time, have them read their journal aloud to the other members of their group. Encourage group members to ask questions to clarify the ideas in the journal entry.

Example:

Red Head	Blue Head	Explain
Changes in Matter	Physical	In physical changes the molecules that make up matter change the way they relate to each other.
	Chemical	In chemical changes, the chemicals bonds are changed.

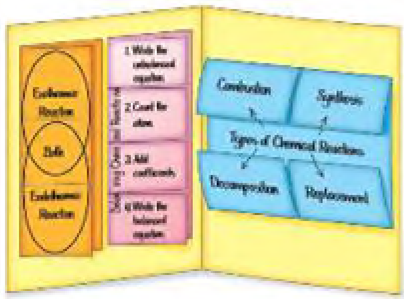
Vocabulary

Study Strategy: Who am I?

This activity will enable students to review vocabulary words from the chapter. Students will first create a list of definitions of words and then play a game using their definitions.

1. Ask students to make a list of the chapter's vocabulary words and then create a description for each vocabulary word starting with the words, "I am. . .". For example, "I am a type of chemical reaction. I like to give off thermal energy."
2. Have one student begin the game by reading their description. Students in the class must guess what vocabulary word that student is describing.
3. The student who correctly guesses the word then reads one of his or her definitions and play continues in the same manner.
4. Continue to play the game until all vocabulary words have been reviewed at least twice or as time allows.

FOLDABLES



Use the Foldables® Chapter Project as a way to connect Key Concepts.

1. Ask students to organize their Foldables® in a way that reflects how the concepts in each Foldable relate to each other.
2. Use glue or staples to hold the sheets together as needed.
3. When complete, ask students to place their Foldables® Chapter Project at the front of the room. Have the class critique and discuss the way in which students have organized their Foldables®.

Use Vocabulary

1 product

2 chemical equation

3 single-replacement

4 decomposition

5 exothermic

6 activation energy

Link Vocabulary and Key Concepts

7 9 synthesis, decomposition, single-replacement (in any order)

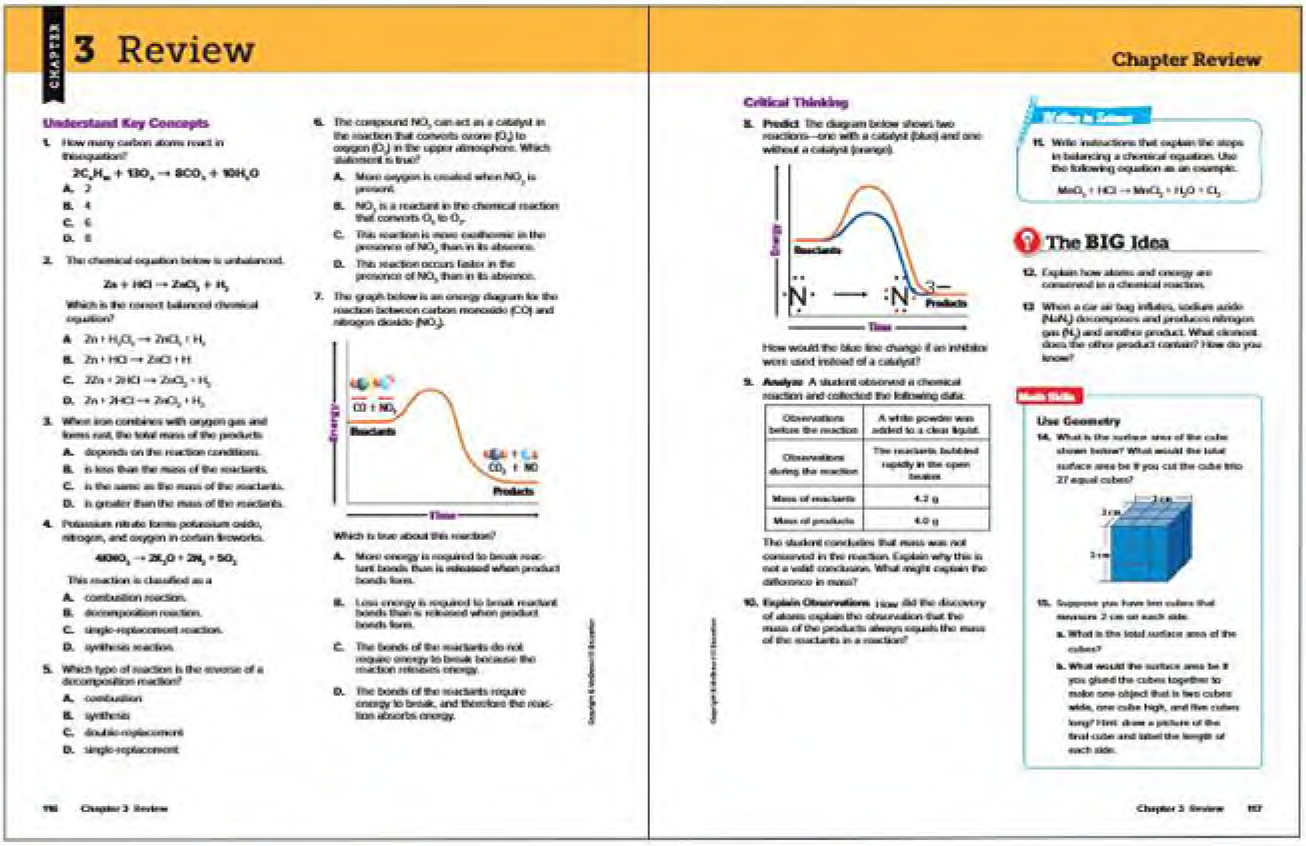
10 13 release or absorption of light, change in odor, formation of a precipitate, formation of a gas (in any order)

14 endothermic

15 exothermic

16 conservation of mass

Teacher Notes



Understand Key Concepts

1 D. 8

2 D. $Zn + 2HCl \rightarrow ZnCl_2 + H_2$

3 C. is the same as the mass of the reactants.

4 B. decomposition reaction.

5 B. synthesis

6 D. This reaction occurs faster in the presence of NO_2 than in its absence.

7 B. Less energy is required to break reactant bonds than is released when product bonds form.

Critical Thinking

8 The blue line would be higher because the inhibitor would increase the activation energy of the reaction.

9 Mass is always conserved in chemical reactions. The reaction produced a gas that was released to the surroundings and not measured on the balance.

10 Atoms are not created or destroyed in a chemical reaction. Atoms simply rearrange, which explains why the mass doesn't change.

Writing in Science

11 Sample answer: First, determine which elements are not balanced. In this reaction, hydrogen, oxygen, and chlorine are not balanced. Place a 2 in front of HCl.

$MnO_2 + 2HCl \rightarrow MnCl_2 + H_2O + Cl_2$

Check each element. Now oxygen is not balanced. Place a 2 in front of H_2O.

$MnO_2 + 2HCl \rightarrow MnCl_2 + 2H_2O + Cl_2$

Check each element. Now hydrogen and chlorine are not balanced. Change the 2 in front of HCl to a 4.

$MnO_2 + 4HCl \rightarrow MnCl_2 + 2H_2O + Cl_2$

Check each element. All elements are now balanced.

The BIG Idea

12 **Atoms of reactants are not created or destroyed but are rearranged and form products. Energy is not created or destroyed but absorbed from or released to the environment.**

13 The other product must contain sodium because the reactant contains sodium and atoms can't be created or destroyed.

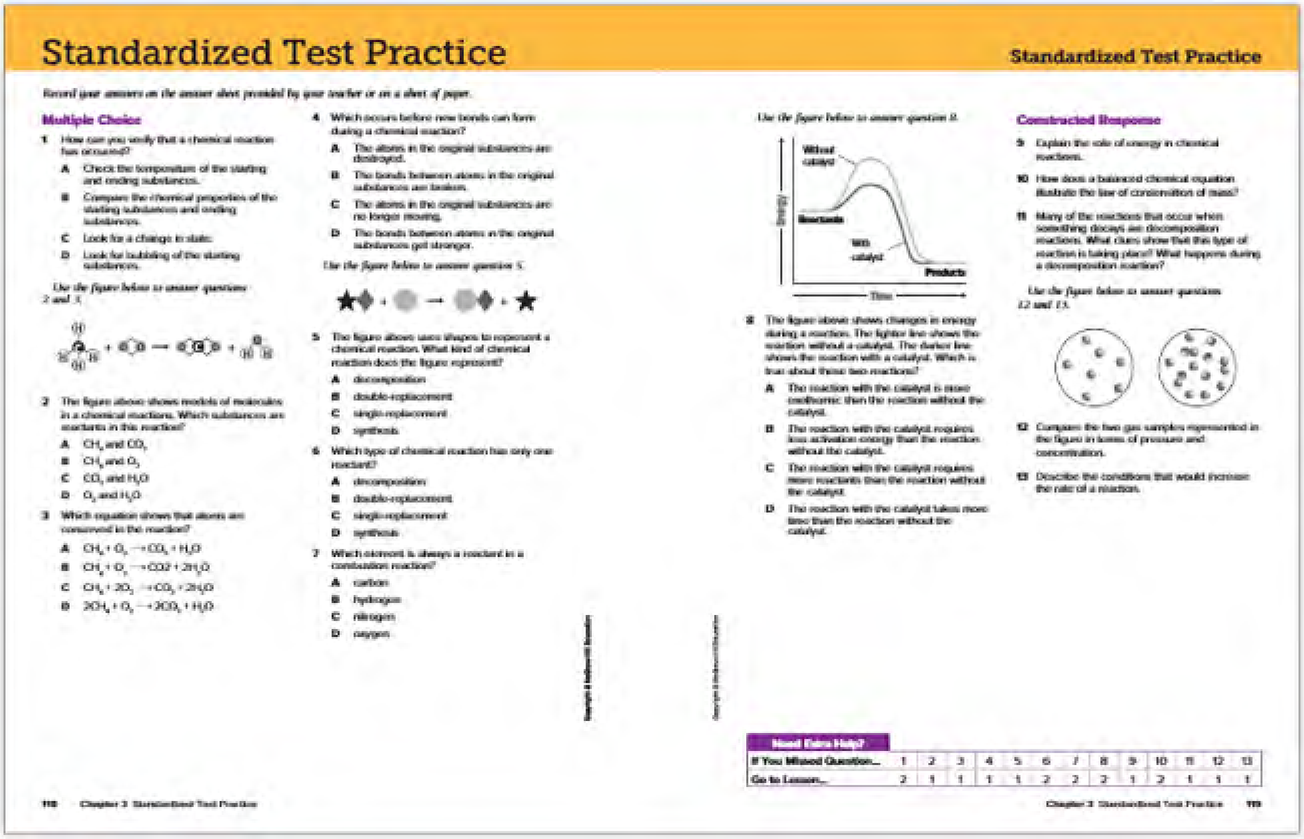
Math Skills

Use Proportions

14. 54 cm^3; 162 cm^2

15. 240 cm^2; 136 cm^2

Teacher Notes



Standardized Test Practice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

Multiple Choice

1 How can you verify that a chemical reaction has occurred?
- **A** Check the temperature of the starting and ending substances.
- **B** Compare the chemical properties of the starting substances and ending substances.
- **C** Look for a change in state.
- **D** Look for bubbling of the starting substances.

Use the figure below to answer questions 2 and 3.

2 The figure above shows models of molecules in a chemical reactions. Which substances are reactants in this reaction?
- **A** CH_4 and CO_2
- **B** CH_4 and O_2
- **C** CO_2 and H_2O
- **D** O_2 and H_2O

3 Which equation shows that atoms are conserved in the reaction?
- **A** $CH_4 + O_2 \rightarrow CO_2 + H_2O$
- **B** $CH_4 + O_2 \rightarrow CO2 + 2H_2O$
- **C** $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
- **D** $2CH_4 + O_2 \rightarrow 2CO_2 + H_2O$

4 Which occurs before new bonds can form during a chemical reaction?
- **A** The atoms in the original substances are destroyed.
- **B** The bonds between atoms in the original substances are broken.
- **C** The atoms in the original substances are no longer moving.
- **D** The bonds between atoms in the original substances get stronger.

Use the figure below to answer question 5.

5 The figure above uses shapes to represent a chemical reaction. What kind of chemical reaction does the figure represent?
- **A** decomposition
- **B** double-replacement
- **C** single-replacement
- **D** synthesis

6 Which type of chemical reaction has only one reactant?
- **A** decomposition
- **B** double-replacement
- **C** single-replacement
- **D** synthesis

7 Which element is always a reactant in a combustion reaction?
- **A** carbon
- **B** hydrogen
- **C** nitrogen
- **D** oxygen

Use the figure below to answer question 8.

8 The figure above shows changes in energy during a reaction. The lighter line shows the reaction without a catalyst. The darker line shows the reaction with a catalyst. Which is true about these two reactions?
- **A** The reaction with the catalyst is more exothermic than the reaction without the catalyst.
- **B** The reaction with the catalyst requires less activation energy than the reaction without the catalyst.
- **C** The reaction with the catalyst requires more reactants than the reaction without the catalyst.
- **D** The reaction with the catalyst takes more time than the reaction without the catalyst.

Constructed Response

9 Explain the role of energy in chemical reactions.

10 How does a balanced chemical equation illustrate the law of conservation of mass?

11 Many of the reactions that occur when something decays are decomposition reactions. What clues show that this type of reaction is taking place? What happens during a decomposition reaction?

Use the figure below to answer questions 12 and 13.

12 Compare the two gas samples represented in the figure in terms of pressure and concentration.

13 Describe the conditions that would increase the rate of a reaction.

Need Extra Help?

If You Missed Question...	1	2	3	4	5	6	7	8	9	10	11	12	13
Go to Lesson...	2	1	1	1	1	2	2	2	1	2	1	1	1

118 Chapter 3 Standardized Test Practice

Chapter 3 Standardized Test Practice 119

Multiple Choice

1 **B—Correct.** The definitive way to verify a chemical change is to check the chemical properties of starting and ending substances. A, C, D—Incorrect. These describe changes in physical properties that might be signs of a chemical change but these could also be associated with physical change.

2 **B—Correct.** A—Incorrect. This includes carbon dioxide, which is a product, C—Incorrect. This describes the products of the reaction. D—Incorrect. This includes water, which is a product.

3 **C—Correct.** A, B, D—Incorrect. These equations are not balanced.

4 **B—Correct.** A—Incorrect. Matter cannot be destroyed. C—Incorrect. Atoms are always moving. D—Incorrect. Strengthening the bonds does not aid in their breaking.

5 **C—Correct.** A—Incorrect. A decomposition reaction would have a single reactant. B—Incorrect. A double-replacement reaction involves two substances changing places. D—Incorrect. A synthesis reaction would have a single product.

6 **A—Correct.** B, C—Incorrect. Single-replacement and double-replacement reactions involve two reactants. D—Incorrect. A synthesis reaction would have multiple reactants and a single product.

7 **D—Correct.** Oxygen is always a reactant in a combustion reaction. A, B, C—Incorrect. These are not necessarily reactants.

8 **B—Correct.** A—Incorrect. A catalyst doesn't change the overall amount of energy absorbed or released in a reaction. C—Incorrect. A catalyst doesn't change the amount of reactant used or products produced in a reaction. D—Incorrect. A catalyst reduces the reaction time of a reaction.

Constructed Response

9. Energy in a chemical reaction is transferred and/or transformed; it is neither created nor destroyed. Some chemical reactions release energy to the environment and others absorb energy from the environment. Some chemical reactions require an input of energy, called activation energy, to begin.

10. Because mass is not created or destroyed, a balanced equation shows that the number of atoms of each element is the same on each side of the reaction arrow. This notation then represents that the mass of matter is the same before and after the reaction takes place.

11. Rotting often involves a change in color and in odor, which are clues that a chemical reaction is taking place. During a decomposition reaction, one larger compound breaks down to form two or more simpler substances.

12. The gas model on the right has more particles. Therefore, the pressure and concentration are both greater in the container on the right.

13. When the pressure (or concentration) of a gaseous reactant is higher, the reaction takes place at a faster rate because the particles collide more often.

Answer Key

Question	Answer
1	B
2	B
3	C
4	B
5	C
6	A
7	D
8	B
9	See extended answer.
10	See extended answer.
11	See extended answer.
12	See extended answer.
13	See extended answer.