Section 7.3

1 FOCUS

Objectives

7.3.1 **Describe** the energy changes that take place during chemical reactions.

7.3.2 **Classify** chemical reactions as exothermic or endothermic.

7.3.3 **Explain** how energy is conserved during chemical reactions.

Reading Focus

Build Vocabulary L2

Word-Part Analysis Tell students that the prefix *exo-* means *out* and the prefix *endo-* means *in*. Have students predict the meaning of the terms *exothermic reaction* and *endothermic reaction* given that the word root *thermo* means *heat*. *(An exothermic reaction gives off heat (energy), while an endothermic reaction takes in heat (energy).)*

Reading Strategy L2

a. Releases energy to the surroundings
b. Absorbs energy from surroundings

2 INSTRUCT

Chemical Bonds and Energy

Build Science Skills L2

Using Models Have students use molecular model kits to make ball-and-stick models for propane, C_3H_8. Explain that the sticks represent bonds and the balls represent atoms in the molecule. Have students count the number of bonds that will break in the combustion of a propane molecule.
Logical, Visual

7.3 Energy Changes in Reactions

Reading Focus

Key Concepts

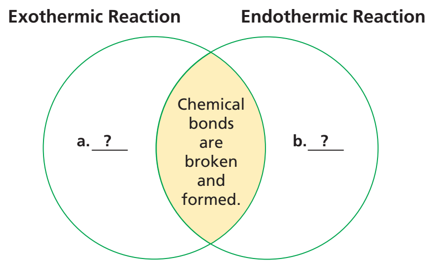
- What happens to chemical bonds during a chemical reaction?
- What happens to energy during a chemical reaction?

Vocabulary

- chemical energy
- exothermic reaction
- endothermic reaction

Reading Strategy

Comparing and Contrasting Copy the Venn diagram. As you read, complete it to show the differences between exothermic and endothermic reactions.



If you've ever had a barbecue, you may have used a gas grill like the one shown in Figure 16. Many types of gas grills use propane, C_3H_8. You can think of a propane grill as the scene of a chemical reaction—specifically, a combustion reaction. The reactants are propane and oxygen, and the products are carbon dioxide and water. However, the description of this reaction is incomplete unless you consider the heat and light produced. Heat, after all, is the reason for using a propane grill.

Figure 16 Many portable barbecue grills burn propane gas.

Chemical Bonds and Energy

The heat produced by a propane grill is a form of energy. When you write the chemical equation for the combustion of propane, you can include "heat" on the right side of the equation.

$$C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O + \text{Heat}$$

This equation states that the heat released in the reaction came from the reactants. **Chemical energy** is the energy stored in the chemical bonds of a substance. A propane molecule has ten single covalent bonds (eight C—H bonds and two C—C bonds). The chemical energy of a propane molecule is the energy stored in these bonds. Likewise, oxygen, carbon dioxide, and water molecules all have energy stored in their chemical bonds.

Section Resources

Print
- ***Reading and Study Workbook With Math Support***, Section 7.3
- ***Transparencies***, Section 7.3

Technology
- ***Interactive Textbook***, Section 7.3
- ***Presentation Pro CD-ROM***, Section 7.3

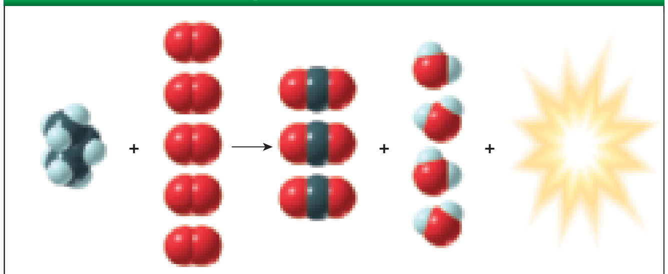
Energy changes in chemical reactions are determined by changes that occur in chemical bonding. **Chemical reactions involve the breaking of chemical bonds in the reactants and the formation of chemical bonds in the products.** In the combustion of propane, the bonds in propane and oxygen molecules are broken, while the bonds in carbon dioxide and water molecules are formed.

Breaking Bonds As Figure 17 illustrates, each propane molecule reacts with five oxygen molecules. In order for the reaction to occur, eight C—H single bonds, two C—C single bonds, and five O═O double bonds must be broken. Breaking chemical bonds requires energy. This is why propane grills have an igniter, a device that produces a spark. The spark provides enough energy to break the bonds of reacting molecules and get the reaction started.

Forming Bonds Figure 17 also shows you that for each molecule of propane burned, three molecules of carbon dioxide and four molecules of water are formed. This means that six C═O double bonds and eight O—H single bonds are formed in the reaction. The formation of chemical bonds releases energy. The heat and light given off by a propane stove result from the formation of new chemical bonds. The bonds form as the carbon, hydrogen, and oxygen atoms in the propane and oxygen molecules are rearranged into molecules of carbon dioxide and water.

Reading Checkpoint ***Does breaking chemical bonds require energy or release energy?***

Propane Combustion



C_3H_8 *propane*	+	$5O_2$ *oxygen*	⟶	$3CO_2$ *carbon dioxide*	+	$4H_2O$ *water*	+	Heat
8 C–H, 2 C–C *bonds broken*		5 O=O *bonds broken*	⟶	6 C=O *bonds formed*		8 O–H *bonds formed*		

Figure 17 In order for the combustion of propane to occur, all the chemical bonds in the reactants (propane and oxygen) must be broken. The formation of the chemical bonds in the products completes the reaction. **Inferring** ***How does the chemical energy of the reactants compare to the chemical energy of the products in this reaction?***

Build Reading Literacy L1

Relate Text and Visuals Refer to page **190D** in this chapter, which provides the guidelines for relating text and visuals.

Have students read the text on pp. 206 and 207 related to energy changes in chemical reactions. Have students use Figures 16 and 17 to describe the path of energy that takes place in the barbecue scene. *(Energy stored in the bonds of the propane stored in the gas tank and the oxygen in the air is released during the combustion reaction. The heat released is absorbed by surroundings, which include the food on the grill.)*
Visual, Logical

Address Misconceptions L2

Many students associate combustion only with explosive reactions. Challenge this misconception by discussing ways in which a fire can burn without a great explosion. For example, simmering soup at low heat on a gas stove uses the combustion of methane. Explain that while combustion reactions are highly exothermic, they are not always accompanied by a blast.
Verbal

Customize for English Language Learners

Using Metaphors
Tell students that chemical energy in chemical reactions can be compared to money in starting a business. It takes money to purchase the merchandise. You can make that money back by selling the merchandise. If you have a product that sells well, you have a profitable business. But, if your merchandise does not sell well, you lose money. Have students come up with their own metaphors for chemical energy and share with the class.

Answer to . . .

Figure 17 *The chemical energy of the products is less than the chemical energy of the reactants.*

Reading Checkpoint *Breaking chemical bonds requires energy.*

Section 7.3 (continued)

Exothermic and Endothermic Reactions

Build Science Skills L2

Observing

ACTIVITY

Purpose Students observe an exothermic process.

Materials beaker, water, thermometer, 1 tsp calcium chloride

Class Time 10 minutes

Procedure Have students fill a beaker with room temperature water and measure its temperature. Then, dissolve 1 tsp of calcium chloride in the water. Have students take the temperature of the solution and identify the process as endothermic or exothermic. Pour the waste solutions down the drain with excess water.

Safety Students should wear gloves and goggles for this activity.

Expected Outcome The temperature increases. The process is exothermic.
Logical, Visual, Group

Use Visuals L1

Figure 18 Have students examine the graphs. Ask, **As you go from left to right in each graph, what happens to the reactants?** *(They react to form the products.)* **What point on each graph represents the highest energy?** *(The energy is highest at each curve's peak.)* **What do the double-headed arrows represent?** *(The double-headed arrows represent the difference in chemical energy between the reactants and the products.)* **Which type of reaction has products with a greater amount of energy than the reactants?** *(The products in an endothermic reaction have a greater amount of chemical energy than the reactants.)*
Visual

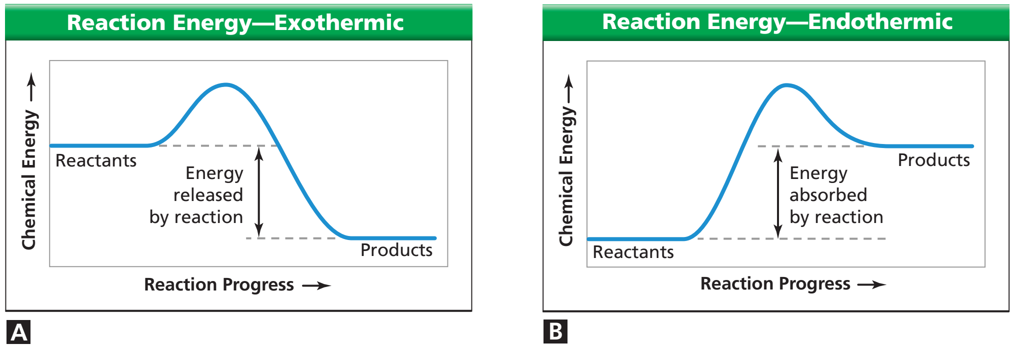


Figure 18 In chemical reactions, energy is either released or absorbed. **A** In an exothermic reaction, energy is released to the surroundings. **B** In an endothermic reaction, energy is absorbed from the surroundings. Using Graphs ***How do the energy diagrams show that energy is conserved in chemical reactions?***

Exothermic and Endothermic Reactions

Recall that physical changes can release or absorb energy. During an exothermic change, such as freezing, energy is released to the surroundings. During an endothermic change, such as melting, energy is absorbed from the surroundings. Energy also flows into and out of chemical changes. **During a chemical reaction, energy is either released or absorbed.**

Exothermic Reactions A chemical reaction that releases energy to its surroundings is called an **exothermic reaction.** In exothermic reactions, the energy released as the products form is greater than the energy required to break the bonds in the reactants.

Combustion is an example of an extremely exothermic reaction. When 1 mole of propane reacts with 5 moles of oxygen, 2220 kJ (kilojoules) of heat is released. You can use this value to replace "heat" in the combustion equation written earlier.

$$C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O + 2220\ \text{kJ}$$

Figure 18A shows how chemical energy changes during an exothermic reaction. Notice that the chemical energy of the reactants is greater than the chemical energy of the products. The difference between these amounts of energy equals the amount of heat given off by the reaction.

In any reaction, the chemical energy reaches a peak before the reactants change into products. This peak represents the amount of energy required to break the chemical bonds of the reactants. Unless reacting particles collide with enough energy to break these bonds, the reaction will not occur. For example, at room temperature, the collisions between propane and oxygen molecules are not energetic enough to result in combustion. However, if you increase the temperature by adding a spark, some of the molecules around the spark move faster and are able to collide with enough energy to react.

Facts and Figures

Activation Energy Reactant particles must collide with enough speed in order to react. Activation energy is the energy required to start a chemical reaction. In an energy diagram, the activation energy is the difference in the energy of the reactants and the energy at the highest point of the curve. Methane gas in a gas stove reacts with oxygen in air to produce carbon dioxide and water. This combustion reaction provides the flame that heats food. However, simply exposing methane to air is not enough for the reaction to take place. Gas stoves have a pilot light or a sparking device that provides the activation energy needed for the reaction to occur. Once the gas is lit, the energy emitted from the exothermic reaction provides the activation energy for the continued burning of methane.

Endothermic Reactions A chemical reaction that absorbs energy from its surroundings is called an **endothermic reaction.** In an endothermic reaction, more energy is required to break the bonds in the reactants than is released by the formation of the products.

Figure 18B shows the energy diagram for an endothermic reaction. Notice that the energy of the products is greater than the energy of the reactants. The difference between these amounts of energy equals the amount of heat that must be absorbed from the surroundings.

When mercury(II) oxide is heated to a temperature of about 450°C, it breaks down into mercury and oxygen, as shown in Figure 19. The decomposition of mercury(II) oxide is an endothermic reaction that can be described by the following equation.

$$2HgO + 181.7\ kJ \longrightarrow 2Hg + O_2$$

Because heat is absorbed, the energy term appears on the left side of the equation. For every 2 moles of HgO that decomposes, 181.7 kJ of heat must be absorbed.

Figure 19 The orange-red powder in the bottom of the test tube is mercury(II) oxide. At about 450°C, mercury(II) oxide decomposes into oxygen gas (which escapes from the test tube) and mercury (droplets of which can be seen collecting on the sides of the test tube).

Conservation of Energy

In an exothermic reaction, the chemical energy of the reactants is converted into heat plus the chemical energy of the products. In an endothermic reaction, heat plus the chemical energy of the reactants is converted into the chemical energy of the products. In both cases, the total amount of energy before and after the reaction is the same. This principle is known as the law of conservation of energy. You will read more about how energy is conserved later.

Section 7.3 Assessment

Reviewing Concepts

1. What happens to chemical bonds as a chemical reaction occurs?
2. How do chemical reactions involve energy?
3. Is the combustion of propane endothermic or exothermic?
4. When propane reacts with oxygen, does the surrounding area become warmer or cooler?
5. Is energy created during an exothermic reaction? Explain.

Critical Thinking

6. **Inferring** Explain why methane does not react with oxygen at room temperature.
7. **Calculating** Methane reacts with oxygen in the following combustion reaction.

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

What bonds are broken when one molecule of methane reacts with two molecules of oxygen?

Connecting Concepts

Chemical Bonds Reread the descriptions of chemical bonds in Sections 6.1 and 6.2. Then, describe the decomposition of mercury(II) oxide. Specify which bonds are ionic and which bonds are covalent.

Conservation of Energy

Address Misconceptions L2

When examining a chemical equation, many students think that energy is being created or destroyed in the reaction. Unlike the situation with conservation of particles, the chemical equation does not clearly show conservation of energy. Challenge this misconception by having students refer to the energy diagrams in Figure 18 for a visual representation of the energy of the reactants and the products.
Visual

3 ASSESS

Evaluate Understanding L2

Have students sketch and label energy diagrams for exothermic and endothermic reactions. Have them discuss the energy diagrams in terms of breaking and forming bonds and conservation of energy.

Reteach L1

Compare and contrast the ways energy is notated in the equation on p. 206, in Figure 17, in Figure 18, and in the equation on p. 208.

Connecting Concepts

Mercury(II) oxide, or HgO, is an ionic compound. The decomposition of HgO can be described by the reaction $2HgO \longrightarrow 2Hg + O_2$. For each O_2 molecule formed by the decomposition of HgO, two ionic Hg—O bonds are broken and one covalent O═O double bond is formed.

Interactive Textbook If your class subscribes to the Interactive Textbook, use it to review key concepts in Section 7.3.

Section 7.3 Assessment

1. Chemical reactions involve the breaking of chemical bonds in the reactants and the formation of chemical bonds in the products.
2. During chemical reactions, energy is either released or absorbed.
3. The combustion of propane is exothermic because it releases energy.
4. Warmer. An exothermic reaction releases heat to the surrounding area.
5. No, energy is not created during an exothermic reaction. The energy released by an exothermic reaction was previously stored as chemical energy in the bonds of the reactants.
6. At room temperature, the collisions between methane molecules and oxygen molecules are not energetic enough to cause a reaction.
7. Four C—H single bonds and two O═O double bonds are broken when one molecule of methane burns.

Answer to . . .

Figure 18 *In Figure 18A, the chemical energy of the reactants equals the chemical energy of the products plus the energy released by the reaction. In Figure 18B, the chemical energy of the reactants plus the energy absorbed by the reaction equals the chemical energy of the products.*