Chemical Reactions and Equations

Energy Changes and Chemical Reactions

Key Concepts

- 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?

Study Coach

Create a Quiz Write a quiz question for each paragraph. Answer the question with information from the paragraph. Then work with a partner to quiz each other.

Key Concept Check

1. Explain Why do chemical reactions involve a change in energy?

Before You Read

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

Before	Statement	After
	5. Reactions that release energy require energy to get started.	
	6. Energy can be created in a chemical reaction.	

Read to Learn

Energy Changes

What is about 1,500 times heavier than a typical car and 300 times faster than a roller coaster? If you guessed a space shuttle, you are right! The energy a space shuttle needs to move this fast comes from a chemical reaction that produces water.

The shuttle's engines burn liquid hydrogen and liquid oxygen. This chemical reaction produces water vapor and a large amount of energy. The energy produced heats the water vapor to high temperatures, causing it to expand rapidly. When the water expands, it pushes the shuttle into orbit. Where does all this energy come from?

Chemical Energy in Bonds

Recall that when a chemical reaction occurs, chemical bonds in the reactants break and new chemical bonds form. Chemical bonds contain a form of energy called chemical energy. When a bond breaks, it absorbs energy from the surroundings. When a bond forms, it releases energy to the surroundings. Some chemical reactions release more energy than they absorb. Some chemical reactions absorb more energy than they release. You can feel this energy change as a change in the temperature of the surroundings. Keep in mind that in all chemical reactions, energy is conserved.

Endothermic Reactions—Energy Absorbed

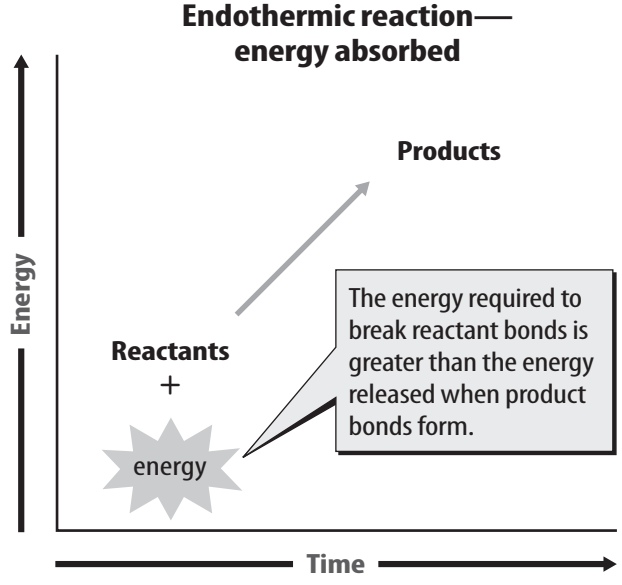
On a very warm day, have you ever heard someone say that the sidewalk was hot enough to fry an egg? To fry, the egg must absorb energy.

Chemical reactions that absorb thermal energy are **endothermic** *reactions.* For an endothermic reaction to continue, energy must be constantly added.

reactants + thermal energy → products

In an endothermic reaction, more energy is required to break the bonds of the reactants than is released when the products form. Therefore, the overall reaction absorbs energy.

The reaction in the figure below is an endothermic reaction. Notice that the products hold more energy than the reactants. The chemical bonds absorbed energy during the reaction.



Exothermic Reactions—Energy Released

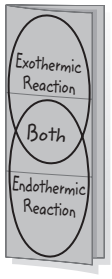
Most chemical reactions release energy as opposed to absorbing it. *An* **exothermic** *reaction is a chemical reaction that releases thermal energy*.

reactants → products + thermal energy

In an exothermic reaction, more energy is released when the products form than is required to break the bonds in the reactants. Therefore, the overall reaction releases energy.

FOLDABLES®

Make a three-tab Venn book to compare and contrast energy in chemical reactions.



Visual Check

2. Interpret Why does the arrow point upward?

_____

_____

_____

Think it Over

3. Analyze The engines of a space shuttle burn liquid hydrogen and liquid oxygen. Is this an endothermic or an exothermic reaction? How do you know?

_____

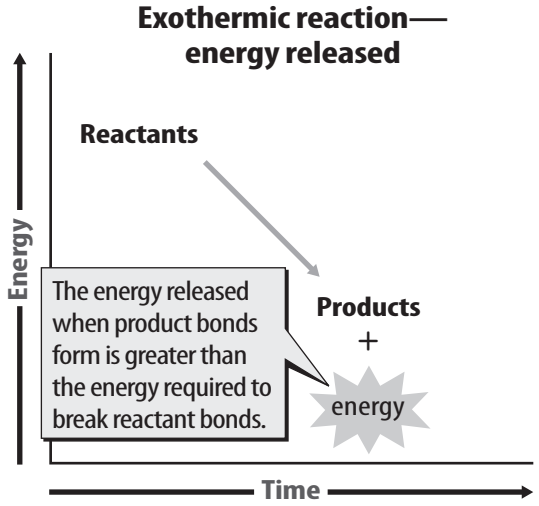
_____

_____

_____

Visual Check

4. Interpret Why does the arrow point downward?



An exothermic reaction releases energy. As a result, the bonds of the reactants contain more energy than the bonds of the products. The reaction shown in the figure above is exothermic. Whether a reaction is endothermic or exothermic depends on the amount of energy contained in the bonds of the reactants and the products.

Key Concept Check

5. Contrast What is the difference between an endothermic reaction and an exothermic reaction?

Activation Energy

You might have noticed that some chemical reactions do not start by themselves. For example, a newspaper does not burn when it comes into contact with oxygen in air. However, if a flame touches the paper, it starts to burn.

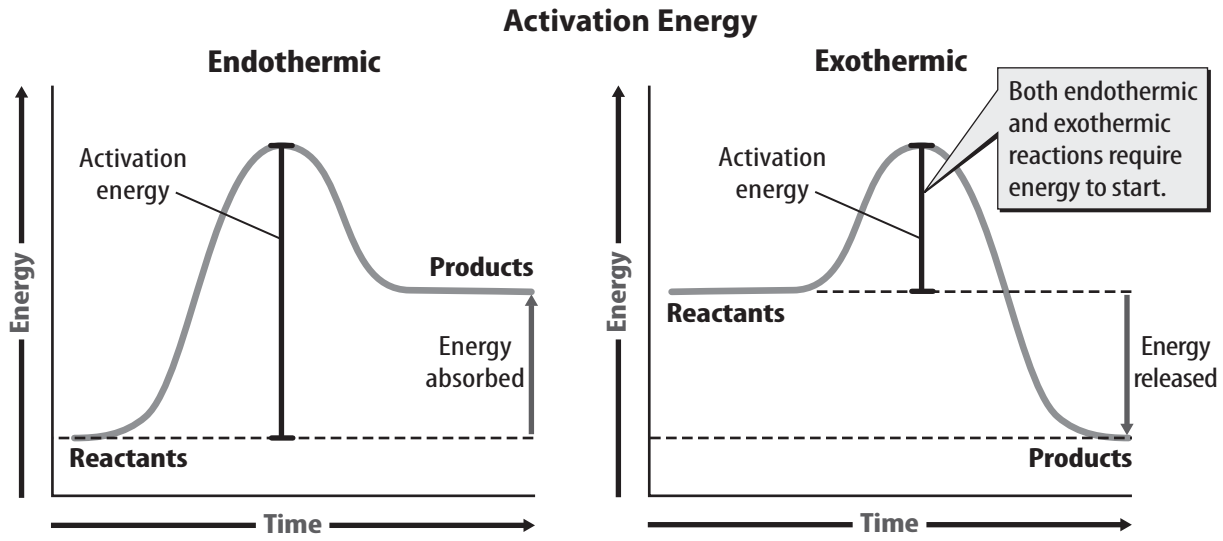
All reactions require energy to start the breaking of bonds. This energy is called activation energy. **Activation energy** *is the minimum amount of energy needed to start a chemical reaction.*

Different reactions have different activation energies. Some reactions, such as the rusting of iron, have low activation energy. The energy in the surroundings is enough to start these reactions.

If a reaction has high activation energy, more energy is needed to start the reaction. For example, wood requires the thermal energy of a flame to start burning. Once the reaction starts, it releases enough energy to keep the reaction going. The figure at the top of the next page shows the role that activation energy plays in endothermic and exothermic reactions.

Reading Check

6. Explain Why doesn't the book on your desk burst into flames?



Reaction Rates

Some chemical reactions, such as the rusting of a bicycle wheel, happen slowly. Other chemical reactions, such as the explosion of fireworks, happen in less than a second. The rate of a reaction is the speed at which the reaction occurs. What controls how fast a chemical reaction occurs?

Recall that particles must collide before they can react. Chemical reactions occur faster if particles collide more often or if the particles move faster when they collide. Several factors affect how often particles collide and how fast particles move.

Surface Area

Surface area is the amount of the exposed outer area of a solid. Increased surface area increases reaction rate. This is because more particles on the surface of a solid come into contact with the particles of another substance. For example, if you place a piece of chalk in vinegar, the chalk reacts slowly with the acid. This is because the acid contacts only the particles on the surface of the chalk. But, if you grind the chalk into powder, more chalk particles contact the acid, and the reaction occurs faster.

Temperature

Imagine a crowded hallway. If everyone in the hallway were running, they would probably collide with each other more often and with more energy than if everyone were walking. This is also true when particles move faster. At higher temperatures, the average speed of particles is greater. This speeds reactions in two ways. First, particles collide more often. Second, collisions with more energy are more likely to break chemical bonds.

Visual Check

7. Analyze How can a reaction absorb energy to start but still be exothermic?

Math Skills

The area of a side of a 1-cm cube is 1 cm × 1 cm or 1 cm^2. The cube has 6 equal sides. Its total surface area is 6 × 1 cm^2 or 6 cm^2. How much surface area is gained by cutting the cube in half?

a. Two surfaces are made, each with an area:

$1\ cm \times 1\ cm = 1\ cm^2$

b. Multiply by the number of new surfaces.

$1\ cm^2 \times 2 = 2\ cm^2$

The surface area is increased by 2 cm^2.

8. Use Geometry How much surface area is gained when a 2 cm cube is cut in half?

Concentration and Pressure

Think of a crowded hallway again. Because the concentration of people is higher in the crowded hallway than in an empty hallway, people probably collide more often. Similarly, increasing the concentration of one or more reactants increases collisions between particles. More collisions result in a faster reaction rate.

In gases, an increase in pressure pushes gas particles closer together. When particles are closer together, more collisions occur.

Reading Check

9. Explain Why does an increase in pressure on a gas speed the reaction rate?

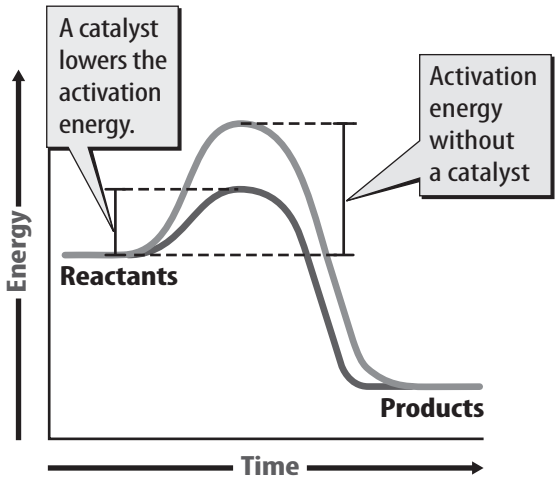
Catalysts

A **catalyst** *is a substance that increases reaction rate by lowering the activation energy of a reaction.* One way catalysts speed reactions is by causing reactant particles to contact each other more often. Look at the figure below. Notice that the activation energy of the reaction is lower with a catalyst than it is without a catalyst. The reaction doesn't change the catalyst, and the catalyst doesn't change the reactants or products. A catalyst doesn't increase the amount of reactant used or amount of product made. A catalyst only makes a reaction happen faster. Catalysts are not reactants in a reaction.

Visual Check

10. Interpret How does a catalyst increase the reaction rate?

Effect of a Catalyst on Activation Energy



Your body is filled with catalysts called enzymes. *An* **enzyme** *is a catalyst that speeds up chemical reactions in living cells.* For example, the enzyme protease (PROH tee ays) breaks the protein molecules in the food you eat into smaller molecules that your intestine can absorb. Without enzymes, these reactions would occur too slowly for life to exist.

Think it Over

11. Apply Protease breaks protein molecules into smaller molecules. This speeds the reaction rate by increasing ___. (Circle your answer.)

a. temperature

b. pressure

c. surface area

Inhibitors

Recall that an enzyme is a molecule that speeds reactions in organisms. However, some organisms, such as bacteria, are harmful to humans. Some medicines contain molecules that attach to enzymes in bacteria. These medicines prevent enzymes in bacteria or viruses from working. If the enzymes in bacteria can't work, the bacteria die and can no longer infect a human. The active ingredients in these medicines are called inhibitors. *An* **inhibitor** *is a substance that slows, or even stops, a chemical reaction.* Inhibitors can slow or stop the reactions caused by enzymes.

Inhibitors are also important in the food industry. Preservatives in food are substances that inhibit, or slow, food spoilage.

Key Concept Check

12. Identify What factors can affect the rate of a chemical reaction?

Mini Glossary

activation energy: the minimum amount of energy needed to start a chemical reaction

catalyst: a substance that increases reaction rate by lowering the activation energy of a reaction

endothermic: a chemical reaction that absorbs thermal energy

enzyme: a catalyst that speeds up chemical reactions in living cells

exothermic: a chemical reaction that releases thermal energy

inhibitor: a substance that slows, or even stops, a chemical reaction

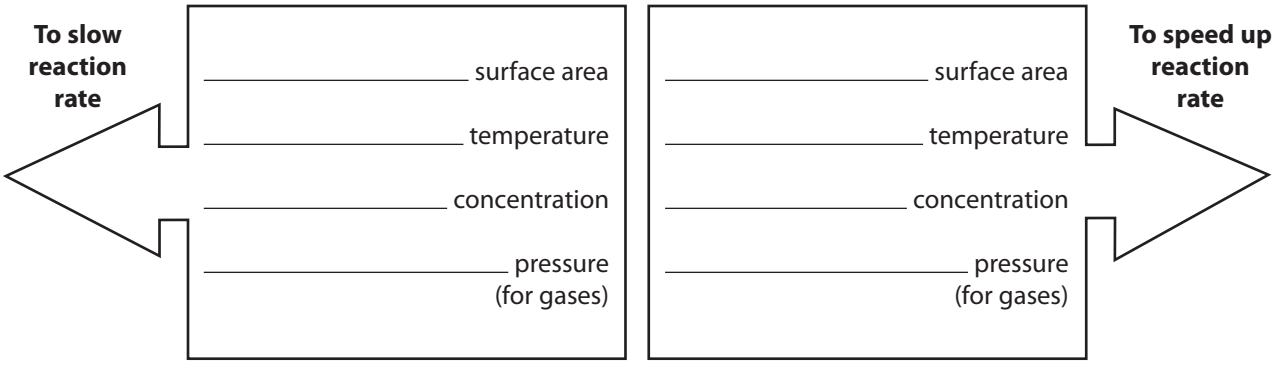
1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains how an enzyme and a catalyst are related.

_____

_____

2. The diagram below summarizes how four factors affect the speed of chemical reactions.

Complete the diagram by writing "increase" or "decrease" next to each factor.



3. In the space below, write a question from your partner's quiz that helped you learn an important concept. Then answer the question.

_____

_____

What do you think NOW?

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

Connect ED

Log on to ConnectED.mcgraw-hill.com and access your textbook to find this lesson's resources.

END OF LESSON