Lesson 3

Energy Changes and Chemical Reactions

Reading Guide

Key Concepts

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 p. 437
exothermic p. 437
activation energy p. 438
catalyst p. 440
enzyme p. 440
inhibitor p. 440

Multilingual eGlossary

PBL Go to the resource tab in ConnectED to find the PBL *Warm It Up!*

Inquiry Energy from Bonds?

A deafening roar, a blinding light, and the power to lift 2 million kg—what is the source of all this energy? Chemical bonds in the fuel store all the energy needed to launch a space shuttle. Chemical reactions release the energy in these bonds.

Launch Lab

20 minutes

Where's the heat?

Does a chemical change always produce a temperature increase?

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.

Time	Temperature (°C)	
	Citric Acid Solution	Sodium Bicarbonate Solution
Starting temp.		
15 s		
30 s		
45 s		
1 min		
1 min, 15 s		
1 min, 30 s		
1 min, 45 s		
2 min		
2 min, 15 sec		

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?

Energy Changes

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

It takes a large amount of energy to launch a space shuttle. The shuttle's main engines burn almost 2 million L of 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. Breaking a bond absorbs energy from the surroundings. The formation of a chemical bond 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.

Key Concept Check Why do chemical reactions involve a change in energy?

Endothermic Reactions—Energy Absorbed

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 on the left in Figure 9 is an endothermic 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.*

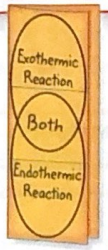
reactants → products + thermal energy

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. The reaction shown on the right in Figure 9 is exothermic.

Key Concept Check What is the difference between an endothermic reaction and an exothermic reaction?

FOLDABLES

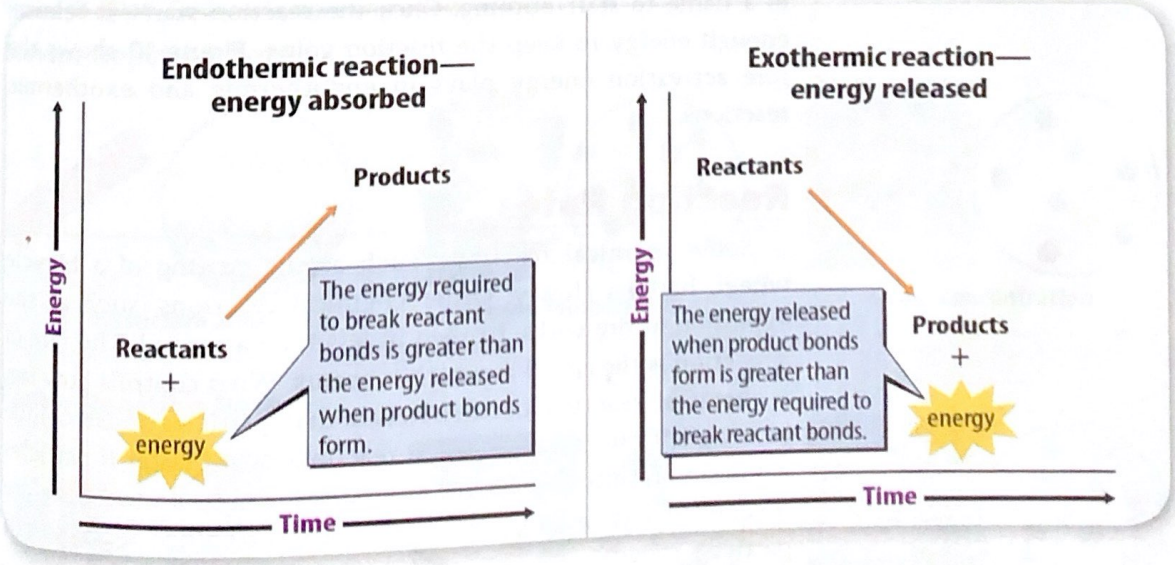
Make a vertical three-tab Venn book. Label it as shown. Use it to compare and contrast energy in chemical reactions.



WORD ORIGIN

exothermic
from Greek *exo-*, means "outside"; and *therm*, means "heat"

Figure 9 Whether a reaction is endothermic or exothermic depends on the amount of energy contained in the bonds of the reactants and the products.



Visual Check Why does one arrow point upward and the other arrow point downward in these diagrams?

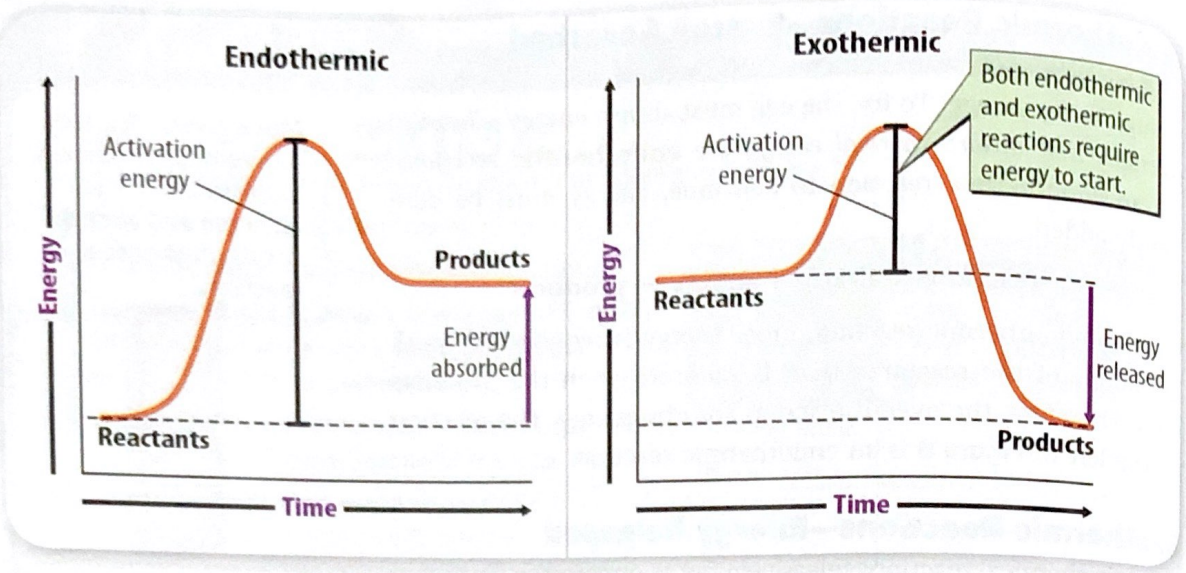


Figure 10 Both endothermic and exothermic reactions require activation energy to start the reaction.

Visual Check How can a reaction absorb energy to start but still be exothermic?

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. Figure 10 shows the role activation energy plays in endothermic and exothermic reactions.

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 it 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 move faster when they collide. There are several factors that affect how often particles collide and how fast particles move.

Reading Check How do particle collisions relate to reaction rate?

Surface Area

Surface area is the amount of exposed, outer area of a solid. Increased surface area increases reaction rate 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.

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. Factors that affect reaction rate are shown in Figure 11.

Math Skills

Use Geometry

The surface area (SA) of one side of a 1-cm cube is 1 cm × 1 cm, or 1 cm^2. The cube has 6 equal sides. Its total SA is 6 × 1 cm^2, or 6 cm^2. What is the total SA of the two solids made when the cube is cut in half?

1. The new surfaces made each have an area of 1 cm × 1 cm = 1 cm^2.
2. Multiply the area by the number of new surfaces. 2 × 1 = 2 cm^2
3. Add the SA of the original cube to the new SA. 6 cm^2 + 2 cm^2 The total SA is 8 cm^2.

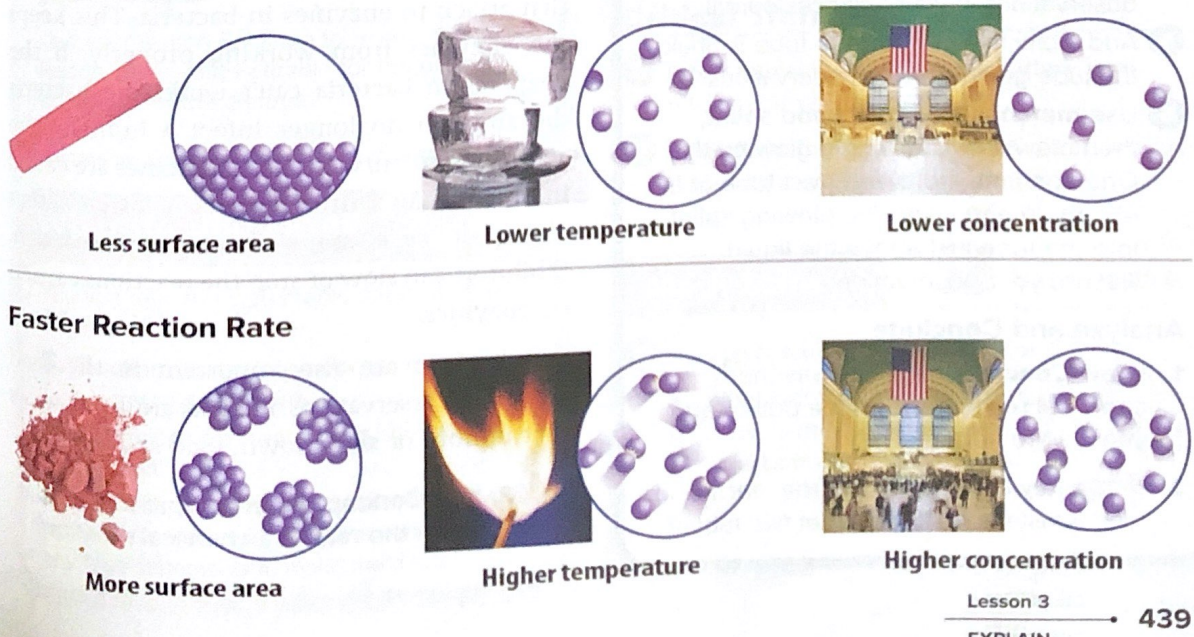
Practice

Calculate the amount of SA gained when a 2-cm cube is cut in half.

Math Practice

Personal Tutor

Figure 11 Several factors can affect reaction rate.



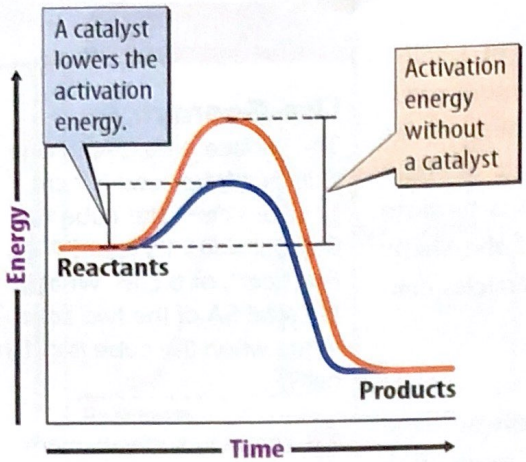


Figure 12 The blue line shows how a catalyst can increase the reaction rate.

MiniLab 20 minutes

Can you speed up a reaction?

Can you speed up the decomposition of hydrogen peroxide (H_2O_2)? The reaction is $H_2O_2 \rightarrow H_2O$ and O_2.

1. Read and complete a lab safety form.
2. Use **tape** to label three **test tubes** *1, 2,* and *3.* Place the tubes in a **test-tube rack.**
3. Add 10 mL of **hydrogen peroxide** to each test tube.
4. Observe tube 1 for changes. Add a small piece of **raw potato** to tube 2. Record observations in your Science Journal.
5. Add a pinch of **dry yeast** to tube 3. Shake the tube gently. Record observations.
6. Use **matches** to light a **wood splint,** then blow it out, leaving a glowing tip. One at a time, hold each test tube at a 45° angle and insert the glowing splint into the tube just above the liquid. Record your observations.

Analyze and Conclude

1. **Draw Conclusions** What was the chemical reaction when the potato and yeast were added?
2. **Key Concept** Why is the reaction in tube 3 faster than in the other two tubes?

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 helping reactant particles contact each other more often. Look at **Figure 12.** Notice that the activation energy of the reaction is lower with a catalyst than it is without a catalyst. A catalyst isn't changed in a reaction, and it doesn't change the reactants or products. Also, a catalyst doesn't increase the amount of reactant used or the amount of product that is made. It only makes a given reaction happen faster. Therefore, catalysts are not considered reactants in a reaction.

You might be surprised to know that 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 can be absorbed by your intestine. Without enzymes, these reactions would occur too slowly for life to exist.

Inhibitors

Recall than 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. This keeps the enzymes from working properly. 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 down, food spoilage.

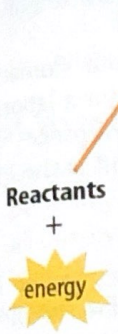
Key Concept Check What factors can affect the rate of a chemical reaction?

Lesson 3 Review

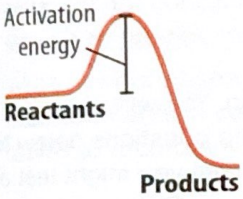
Online Quiz

Visual Summary

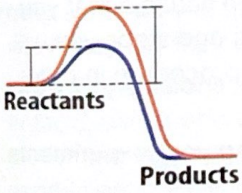
Endothermic



Chemical reactions that release energy are exothermic, and those that absorb energy are endothermic.



Activation energy must be added to a chemical reaction for it to proceed.



Catalysts, including enzymes, speed up chemical reactions. Inhibitors slow them down.

FOLDABLES

Use your lesson Foldable to review the lesson. Save your Foldable for the project at the end of the chapter.

What do you think NOW?

You first read the statements below at the beginning of the chapter.

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

Did you change your mind about whether you agree or disagree with the statements? Rewrite any false statements to make them true.

Use Vocabulary

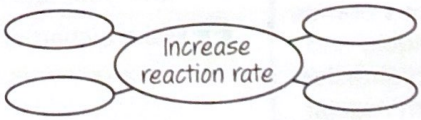
1. The smallest amount of energy required by reacting particles for a chemical reaction to begin is the _____.

Understand Key Concepts

2. How does a catalyst 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

Math Practice

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?

Lab

2 class periods

Design an Experiment to Test Advertising Claims

Antacids contain compounds that react with excess acid in your stomach and prevent a condition called heartburn. Suppose you work for a laboratory that tests advertising claims about antacids. What kinds of procedures would you follow? How would you decide which antacid is the most effective?

Materials


graduated cylinder


balance


droppers

baking soda


plastic spoon

Also needed: various brands of liquid and solid antacids (both regular and maximum strength), beakers, universal indicator in dropper bottle, 0.1M HCl solution, stirring rods

Safety

Ask a Question

Ask a question about the claims that you would like to investigate. For example: what does *most effective* mean? What would make an antacid the strongest?

Make Observations

1. Read and complete a lab safety form.
2. Study the selection of antacids available for testing. You will use a 0.1M HCl solution to simulate stomach acid. Use the questions below to discuss with your lab partners which advertising claim you might test and how you might test it.
3. In your Science Journal, write a procedure for each variable that you will test to answer your question. Include the materials and steps you will use to test each variable. Place the steps of each procedure in order. Have your teacher approve your procedures.
4. Make a chart or table to record observations during your experiments.

Questions

Which advertising claim will I test? What question am I trying to answer?
What will be the independent and the dependent variables for each test? Recall that the independent variable is the variable that is changed. A dependent variable changes when you change the independent variable.
What variables will be held constant in each test?
How many different procedures will I use, and what equipment will I need?
How much of each antacid will I use? How many antacids will I test?
How will I use the indicator?
How many times will I do each test?
How will I record the data and observations?
What will I analyze to form a conclusion?

Form a Hypothesis

5 Write a hypothesis for each variable. Your hypothesis should identify the independent variable and state why you think changing the variable will alter the effectiveness of an antacid tablet.

Test Your Hypothesis

6 On day 2, use the available materials to perform your experiments. Accurately record all observations and data for each test.

7 Add any additional tests you think you need to answer your questions.

8 Examine the data you have collected. If the data are not conclusive, what other tests can you do to provide more information?

9 Write all your observations and measurements in your Science Journal. Use tables to record any quantitative data.

Analyze and Conclude

10 **Infer** What do you think advertisers mean when they say their product is most effective?

11 **Draw Conclusions** If you needed an antacid, which one would you use, based on the limited information provided from your experiments? Explain your reasoning.

12 **Analyze** Would breaking an antacid tablet into small pieces before using it make it more effective? Why or why not?

13 **The Big Idea** How does understanding chemical reactions enable you to analyze products and their claims?

Communicate Your Results

Combine your data with other teams. Compare the results and conclusions. Discuss the validity of advertising claims for each brand of antacid.

Inquiry Extension

Research over-the-counter antacids that were once available by prescription only. Do they work in the same way as the antacids you tested? Explain.

Lab Tips

- ☑ Think about how you might measure the amount of acid the tablet neutralizes. Would you add the tablet to the acid or the acid to the tablet? What does the indicator show you?
- ☑ Try your tests on a small scale before using the full amounts to see how much acid you might need.
- ☑ Always get your teacher's approval before trying any new test.

Remember to use scientific methods.