7.4 Reaction Rates

1 FOCUS

Objectives

7.4.1 **Explain** what a reaction rate is.
7.4.2 **Describe** the factors affecting chemical reaction rates.

Reading Focus

Key Concept

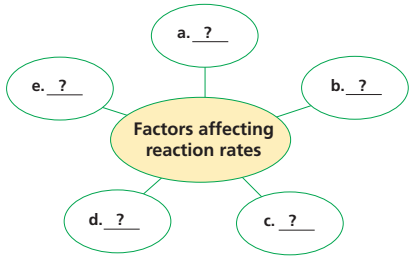
- What does a reaction rate tell you?
- What factors cause reaction rates to change?

Vocabulary

- reaction rate
- catalyst

Reading Strategy

Building Vocabulary
Copy the partially completed web diagram at the right. Then, as you read, complete it with key terms from this section.



Build Vocabulary L2

LINCS Have students use the LINCS strategy to learn and review the terms *reaction rate, surface area, concentration,* and *catalyst*. In LINCS exercises, students **L**ist what they know about each term, **I**magine a picture that describes the word, **N**ote a "sound-alike" word, **C**onnect the terms to the sound-alike word by making up a short story, and then perform a brief **S**elf-test.

Reading Strategy L2

a. Temperature **b.** Surface area
c. Stirring **d.** Concentration
e. Catalysts

2 INSTRUCT

Reactions Over Time

Build Math Skills L1

Ratios and Proportions
To help students understand reaction rate, review other rates that they might be familiar with. As an example of a rate, discuss speed as the ratio of distance traveled over time. In your discussion, be sure that students pay particular attention to the units (miles/hour, etc.). **Logical**

Direct students to the **Math Skills** in the **Skills and Reference Handbook** at the end of the student text for additional help.

Build Reading Literacy L1

Outline Refer to page **156D** in **Chapter 6**, which provides the guidelines for outlining.

Have students read the section. Then, have students use the headings as major divisions in an outline. Allow students to refer to their outlines when answering the questions in the Section 7.4 Assessment. **Visual**

Figure 20 A cyclist burns the Calories in a banana faster than a person walking would. But burning the banana outside the body would release the energy of the banana even faster.

You may have heard of athletes "burning Calories" when they exercise. A Calorie is a unit of energy used in the field of nutrition. The average banana, for instance, contains about 100 Calories. The cyclist in Figure 20 can use up, or burn, as many as 10,000 Calories during the course of a race. That adds up to a lot of bananas!

If you eat a banana, you provide your body with about 100 Calories to burn. This energy is released in a series of reactions that take place inside your body. A much faster way of releasing the energy contained in a banana is to burn it—outside the body—in a combustion reaction. In both cases, the total amount of energy released is the same. However, the time it takes for the energy to be released is different in each case.

Reactions Over Time

The progress of any chemical reaction can be measured over time. Different reactions have different durations. Some reactions, such as the explosion of TNT, happen almost instantaneously. Other reactions, such as tree leaves changing color during autumn, happen gradually.

Any change that happens over a period of time can be expressed as a rate. For example, speed is the rate that distance changes over time. A **reaction rate** is the rate at which reactants change into products over time. **Reaction rates tell you how fast a reaction is going.** That is, how fast the reactants are being consumed, how fast the products are being formed, or how fast energy is being absorbed or released.

Section Resources

Print
- ***Reading and Study Workbook With Math Support,*** Section 7.4
- ***Transparencies,*** Section 7.4

Technology
- ***Interactive Textbook,*** Section 7.4
- ***Presentation Pro CD-ROM,*** Section 7.4
- ***Go Online,*** NSTA SciLinks, Factors affecting reaction rate

Factors Affecting Reaction Rates

Recall that chemical reactions involve collisions between particles of reactants. The reaction rate depends on how often these particles collide. If the collisions occur more frequently, then the reaction rate increases. If the collisions occur less frequently, then the reaction rate decreases. Almost any reaction rate can be changed by varying the conditions under which the reaction takes place. **Factors that affect reaction rates include temperature, surface area, concentration, stirring, and catalysts.**

Temperature Suppose you are frying an egg in a frying pan. What happens if you increase the heat under the pan? The hotter the pan, the faster the egg will cook. Generally, an increase in temperature will increase the reaction rate, while a decrease in temperature will decrease the reaction rate. For instance, you store milk in a refrigerator to slow down the reactions that cause the milk to spoil. These reactions don't stop completely. Even milk stored in a refrigerator will eventually spoil. But the rate of spoiling decreases if the milk is kept cold.

Increasing the temperature of a substance causes its particles to move faster, on average. Particles that move faster are both more likely to collide and more likely to react. If the number of collisions that produce reactions increases, then the reaction rate increases.

Reading Checkpoint ***How does temperature affect reaction rates?***

Surface Area Grain may not strike you as a dangerous material, but it can be explosive under the right conditions. The cause of the fire in Figure 21 was a combustion reaction between grain dust (suspended in the air) and oxygen. The rate of combustion was very rapid due to the small particle size of the grain dust.

The smaller the particle size of a given mass, the larger is its surface area. Imagine using a newspaper to cover the floor of a room. If you keep all the sections folded together, you can only cover a small area. However, if you separate the newspaper into pages and lay them out like tiles, you can cover a much larger area with the same mass of paper.

An increase in surface area increases the exposure of reactants to one another. The greater this exposure, the more collisions there are that involve reacting particles. With more collisions, more particles will react. This is why increasing the surface area of a reactant tends to increase the reaction rate.

Go Online NSTA SciLinks

For: Links on factors affecting reaction rate
Visit: www.SciLinks.org
Web Code: ccn-1074

Figure 21 This grain elevator in Potlatch, Idaho, exploded when grain dust reacted with oxygen in the air.
Applying Concepts ***How does surface area affect reaction rates?***

Customize for Inclusion Students

Visually Impaired
For visually impaired students, consider performing the above demonstration using a reaction that can be observed audibly. For example, place one effervescent tablet in a beaker of cold water and a second effervescent tablet in a beaker of hot water. Have students gather closely around the reaction, or find a way to amplify the reaction sounds. Students should be able to hear a difference in the rates of gas evolution.

Factors Affecting Reaction Rates

Build Science Skills

L2

Calculating

ACTIVITY

Purpose Students learn how to increase surface area.

Materials clay, rulers, plastic knives

Class Time 10 minutes

Procedure Have students make a clay cube, measure its dimensions, and calculate its surface area. Then, have students cut the clay cube in half and calculate the total surface area of the two pieces. Ask, **How does cutting the clay cube in half affect its surface area?** *(Surface area increases.)*

Expected Outcome The more pieces the clay cube is cut into, the greater the surface area becomes. **Logical, Visual**

Teacher Demo

Temperature and Rate

L2

Purpose Students observe the effect of temperature on reaction rate.

Materials 2 chemical light sticks, 2 large beakers, hot water, ice water

Procedure Students will observe the same reaction taking place at two different temperatures. Fill one beaker with hot water and the other with ice water. Turn off the room lights. Place an activated light stick in each beaker. Explain that the light sticks glow due to a chemical reaction that gives off light.

Expected Outcome The light stick in hot water will glow more than the one in cold water. **Visual**

Go Online NSTA SciLinks

Download a worksheet on factors affecting reaction rate for students to complete, and find additional teacher support from NSTA SciLinks.

Answer to . . .

Figure 21 *A surface area increase generally increases the reaction rate.*

Reading Checkpoint *Increasing the temperature generally increases the reaction rate.*

Quick Lab

Observing the Action of Catalysts

L2

Objective
After completing this activity, students will be able to
- describe how a catalyst is able to promote a chemical reaction.

Address Misconceptions

Many students see the formation of a new substance with new properties as simply happening, rather than as a result of atoms rearranging. Catalysts can further confuse the issue because they aid the progress of a reaction without being changed by the reaction. Explain that in this Quick Lab, the same reaction takes place in all four test tubes. Use molecular models of hydrogen peroxide to show how the atoms in two H_2O_2 molecules are rearranged to form two water molecules, H_2O, and one molecule of oxygen, O_2.

Skills Focus Observing, Formulating Hypotheses

Prep Time 15 minutes

Advance Prep Provide a 3% solution of hydrogen peroxide (typical strength sold in stores) solution and 0.1 M $CuCl_2$ (clearly labeled). To make a 0.1 M solution of $CuCl_2$, dissolve 13.5 g $CuCl_2$ in enough water to make 1 L of solution.

Class Time 20 minutes

Safety Review the information in the MSDS for each compound with students before performing the lab. Make sure that students wear safety goggles, lab aprons, and plastic disposable gloves. Avoid skin contact with the compounds, as some are irritants. Students should wash their hands with soap or detergent before leaving the laboratory.

Expected Outcome The platinum wire, manganese dioxide, and raw potato catalyze the release of oxygen bubbles. Copper chloride does not.

Analyze and Conclude
1. The platinum wire produced moderate bubbling, MnO_2 produced vigorous bubbling, $CuCl_2$ produced no reaction, and potato produced foam.
2. MnO_2; potato
3. This test tube served as the control.
Visual, Group

Quick Lab

Observing the Action of Catalysts

Materials

5 test tubes, test-tube rack, marking pencil, dropper pipet, wood splint, platinum wire, 0.1 g manganese dioxide (MnO_2), 5 drops of copper(II) chloride ($CuCl_2$) solution, 0.1 g raw potato, graduated cylinder, 25 mL hydrogen peroxide (H_2O_2)

Procedure

1. Label the 5 test tubes from A to E with the marking pencil.
2. Put a small piece of platinum wire in test tube A. Add a tiny amount (about the tip of the wood splint) of MnO_2 to test tube B. Use the dropper pipet to put 5 drops of $CuCl_2$ in test tube C. Put a piece of potato in test tube D. Test tube E should remain empty for now. **CAUTION** *MnO_2 and $CuCl_2$ are toxic.*
3. Carefully add 5 mL of hydrogen peroxide to test tube A. **CAUTION** *Be careful when using chemicals.* Observe how fast the bubbles are produced.
4. Repeat Step 3 with test tubes B through E.

Analyze and Conclude

1. **Observing** What effect did the platinum wire, MnO_2, $CuCl_2$, and the potato have on the rate at which the bubbles were produced in the hydrogen peroxide?
2. **Comparing and Contrasting** Which catalyst(s) caused the reaction to go the fastest? The slowest?
3. **Inferring** Why did you put only hydrogen peroxide in test tube E?

Stirring You can also increase the exposure of reactants to each other by stirring them. For example, when you wash your clothes in a washing machine, particles of detergent react with particles of the stains on your clothes. This reaction would go slowly if you just left your clothes soaking in a tub of water and detergent. A washing machine speeds up the reaction by stirring the contents back and forth. Collisions between the particles of the reactants are more likely to happen. Stirring the reactants will generally increase the reaction rate.

Figure 22 The dye solution in the left beaker is more concentrated than the solution in the right. Increasing the concentration of the dye increases the rate of color change in the material.

Concentration Another way you can change the reaction rate is to change the concentration of the reactants. Concentration refers to the number of particles in a given volume. The more reacting particles that are present in a given volume, the more opportunities there are for collisions involving those particles. The reaction rate is faster.

Both of the beakers in Figure 22 contain a piece of material dipped in dye solution. Dyeing is a chemical reaction in which dye particles react with the particles of the material being dyed. The material dipped in the more concentrated dye becomes colored more quickly.

For gases, concentration changes with pressure. The greater the pressure of a gaseous reactant, the greater is its concentration, and the faster is the reaction rate.

Facts and Figures

Biological Catalysts
Catalysts that speed up reactions in biological systems are called enzymes. See Section 9.4 for a definition of *enzyme*. Enzymes help carry out many of the reactions that take place in the human body. For example, the enzyme lactase helps your body break down lactose, a carbohydrate found in milk. People with lactose intolerance do not produce enough lactase to properly digest milk products.

Catalysts Sometimes you can change a reaction rate by using catalysts. A **catalyst** is a substance that affects the reaction rate without being used up in the reaction. Chemists often use catalysts to speed up a reaction or enable a reaction to occur at a lower temperature. In the making of sulfuric acid, one of the steps involved is the reaction of sulfur dioxide with oxygen to form sulfur trioxide. This reaction happens very slowly without a catalyst such as vanadium(V) oxide.

$$2SO_2 + O_2 \xrightarrow{V_2O_5} 2SO_3$$

Since the catalyst is neither a reactant nor a product, it is written over the arrow. Because the catalyst is not consumed, it can be used to speed up the same reaction over and over again.

Recall that in order for a reaction to take place, the reacting particles must collide with enough energy to break the chemical bonds of those particles. As shown in Figure 23, a catalyst lowers this energy barrier. One way that a catalyst can do this is by providing a surface on which the reacting particles can come together. Imagine that you go to a party and make several new friends. By bringing people together, the party has made it easier for you to form those friendships. Similarly, a catalyst can "invite" reacting particles together so that they are more likely to react.

Reaction Energy—Catalyzed and Uncatalyzed

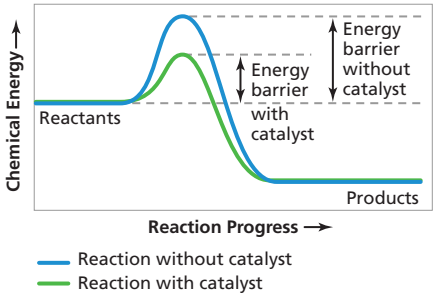


Figure 23 The graph above shows how a catalyst lowers the amount of energy required for effective collisions between reacting particles.
Using Graphs ***In an exothermic reaction, how does a catalyst affect the amount of energy released?***

Section 7.4 Assessment

Reviewing Concepts

1. What does a reaction rate tell you?
2. What five factors affect reaction rates?
3. Explain why reactions take place faster at higher temperatures.
4. When you add baking soda to vinegar, the mixture fizzes as carbon dioxide gas is produced. Suppose you added water to the vinegar before you mixed it with the baking soda. What do you think would happen to the rate of carbon dioxide production?
5. How does a catalyst make a reaction go faster?
6. Platinum is a catalyst for the decomposition of hydrogen peroxide into water and oxygen.

$$2H_2O_2 \xrightarrow{Pt} 2H_2O + O_2$$

What would you expect to see if platinum were added to hydrogen peroxide solution?

Critical Thinking

7. **Applying Concepts** Explain why, if you want to store uncooked hamburger meat for a month, you put it in a freezer rather than a refrigerator.
8. **Evaluating** The reaction between magnesium and hydrochloric acid produces hydrogen. If you increase the concentration of HCl, the reaction takes place faster. Could HCl be considered a catalyst for this reaction? Explain your answer.

Writing in Science

Compare and Contrast Paragraph Write a paragraph explaining how temperature, concentration, surface area, and catalysts affect reaction rates.

Use Visuals

L1

Figure 23 Have students examine the effect of catalysts on energy barriers. Ask, **What do the two lines represent?** *(One line represents the chemical energy as the reaction with the catalyst progresses. The other line represents the chemical energy as the reaction without the catalyst progresses.)* **How does carrying out a reaction in the presence of a catalyst affect the energy barrier of the reaction?** *(The energy barrier for the reaction is less in the presence of the catalyst.)* **How does carrying out a reaction in the presence of a catalyst affect the energy of the reactants and products?** *(The energy of the reactants and products is unchanged by the presence of the catalyst.)* **Visual**

3 ASSESS

Evaluate Understanding

L2

Have students make flashcards that list the ways they could increase the rate of a reaction, with examples on the back of how each factor affects reaction rates. Have students quiz each other.

Reteach

L1

As a class, list five factors that affect reaction rate. Then, have students give an example of each and explain why the factor affects reaction rate.

Writing in Science

Factors that affect the rates of chemical reactions include temperature, concentration, surface area, and the presence of catalysts. Increasing the temperature, surface area of the reactants, or concentration of the reactants generally increases the reaction rate. Catalysts can speed up reactions by providing a surface on which the reacting particles can come together.

Section 7.4 Assessment

1. How fast a chemical reaction is going
2. Temperature, concentration, surface area, stirring, and catalysts
3. Reacting particles move faster on average at higher temperatures. As a result, they collide with each other more often and with greater energy, and the reaction rate increases.
4. The CO_2 production would occur at a slower rate because you have diluted the vinegar. Decreasing the concentration of a reactant decreases the reaction rate.
5. A catalyst makes a reaction go faster by lowering the energy barrier required to break the bonds of the reacting particles.
6. You would see oxygen bubbles because platinum catalyzes the reaction.
7. A freezer is colder than a refrigerator, so the reactions responsible for spoiling the meat will take place more slowly in the freezer.
8. No, HCl cannot be considered a catalyst for the reaction because it is a reactant (and is used up during the reaction). A catalyst is neither a reactant nor a product.

Answer to . . .

Figure 23 *A catalyst does not affect the amount of energy released by the reaction. (The chemical energy of the reactants and the products does not change with the addition of a catalyst.) It does, however, lower the amount of energy required to break the chemical bonds of the reactants.*