6.2 Factors Affecting the Rate of Chemical Reactions

Understanding the factors that affect reaction rates helps chemists speed up or slow down chemical reactions. Four main factors affect the rate of chemical reactions: temperature (hotter is faster), surface area (the more surface contact between reactants, the faster the reaction), concentration (the greater the concentration, the faster the reaction rate), and the presence of a catalyst (the catalyst helps the reaction go more quickly but is still present in the same amount at the end of the reaction).

Words to Know

catalyst
catalytic converter
rate of reaction
surface area

Many chemical reactions happen quickly, sometimes at tremendous rates. For example, chemicals that burn slowly under usual conditions can react explosively in their powder form. The increased contact between air and powder can be enough to blow up an entire grain silo. This is a real concern for people who work in or live close to granaries, coal mines, and other industrial operations, such as flour mills, where powders are manufactured, used, or packaged.

Other chemical reactions occur much more slowly and can take many hundreds or even thousands of years to complete. You may have observed evidence of the slow rusting of a bicycle chain (Figure 6.12). Unless a bicycle chain is protected with a coating of oil, it will eventually become too rusted to use, but this can take years.

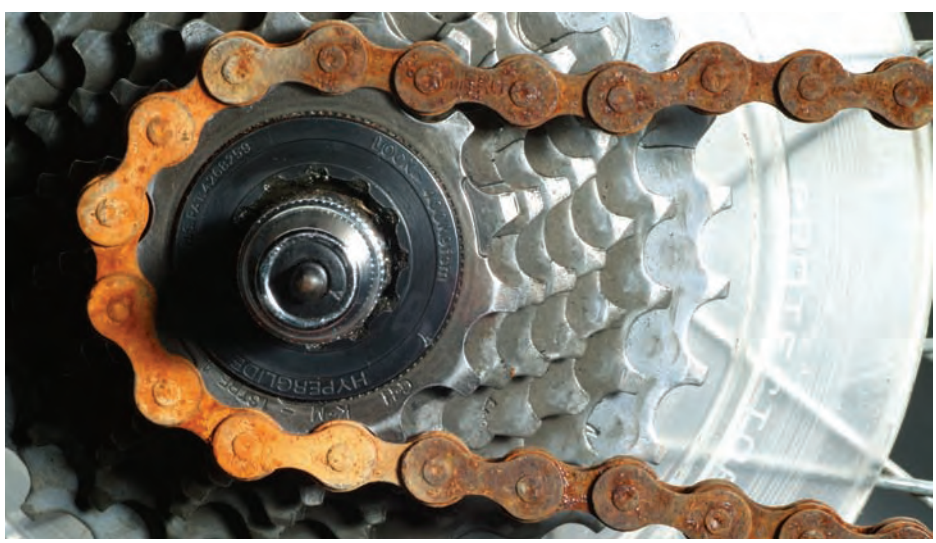

Figure 6.12 Rusting can seriously damage the parts of a bicycle.

Did You Know?

The conversion of graphite into diamond, both of which are made of pure carbon, happens faster when the graphite is compressed at high temperatures and pressures.

In a chemical reaction, how quickly or slowly reactants turn into products is called **rate of reaction**. A reaction that takes a long time has a low reaction rate. A reaction that occurs quickly has a high reaction rate. A *rate* describes how quickly or slowly a change occurs. Every chemical reaction proceeds at a definite rate. However, you can speed up or slow down the rate of a chemical reaction.

6-2A Increasing Reaction Rate

Find Out ACTIVITY

Teacher Demonstration

In this activity, your teacher will demonstrate three ways to increase the rate of a reaction. See if you can identify which factors might be involved in the rate increase.

Safety

- Avoid touching all reactants and products.
- Follow your teacher's directions regarding using open flames.
- Do not remove any materials from the science room.

Materials

- three 100 mL beakers
- hydrochloric acid solutions (3 M, 1 M, and 0.1 M)
- magnesium ribbon
- 50 cm sheet of aluminum foil
- masking tape
- sifted flour
- small plastic bowl
- candle
- matches or flame striker
- sifter
- 200 mL graduated cylinder
- plastic pan
- dish soap
- food colouring
- potassium iodide powder
- hydrogen peroxide solution
- wooden splint

What to Do

Demonstration 1 Single Replacement Reaction between Magnesium and Hydrochloric Acid

1. Fill each of three 100 mL beakers with about 75 mL of a different concentration of hydrochloric acid solution. Label them 3 M, 1 M, and 0.1 M. (The concentration unit, M, stands for molar. A 1 M solution is 10 times more concentrated than a 0.1 M solution.)
2. Cut three 5 cm strips of magnesium ribbon.
3. Drop one magnesium strip into each beaker, and observe. Record your observations.
4. Clean up and put away the equipment you have used.

Demonstration 2 Combustion of Flour

5. Roll a sheet of aluminum foil into a tube, and tape the edges together.
6. Measure about 30 mL of sifted flour into a small plastic bowl.
7. Light a candle and hold the aluminum tube above it. Drop the flour into the tube from the top by pouring it through a sifter held above the tub. Observe. Record your observations.
8. Clean up and put away the equipment you have used.

Demonstration 3 Decomposition of Hydrogen Peroxide

9. Place a 200 mL graduated cylinder into a plastic pan (to catch any spills).
10. Add about 1 mL of soap and a few drops of food colouring to a 200 mL graduated cylinder.
11. Add about 1 mL of potassium iodide (KI) powder to the mixture.
12. Add 50 mL of hydrogen peroxide solution ($H_2O_2(aq)$) to the mixture. Observe. Record your observations.
13. Light a wooden splint. Extinguish the flame, then plunge the glowing splint into the soap bubbles that have been produced. Observe. Record your observations.
14. Clean up and put away the equipment you have used.

What Did You Find Out?

Discuss the following as a class.

1. What is the connection between the concentration of a reactant and the rate of the chemical reaction?
2. (a) What factor was responsible for increasing the rate of combustion of flour?
   (b) What are several real world situations where this factor might apply to reactions?
3. (a) What factor was responsible for speeding up the decomposition of hydrogen peroxide?
   (b) Most chemical reactions in your body are sped up in this fashion. What is the biological term for the kind of substance that speeds up reactions in living things?

6-2A Increasing Reaction Rate

Teacher Demonstration

In this activity, your teacher will demonstrate three ways to increase the rate of a reaction. See if you can identify which factors might be involved in the rate increase.

Safety

- Avoid touching all reactants and products.
- Follow your teacher's directions regarding using open flames.
- Do not remove any materials from the science room.

Materials

- three 100 mL beakers
- hydrochloric acid solutions (3 M, 1 M, and 0.1 M)
- magnesium ribbon
- 50 cm sheet of aluminum foil
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- sifted flour
- small plastic bowl
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- hydrogen peroxide solution
- wooden splint

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2. Cut three 5 cm strips of magnesium ribbon.
3. Drop one magnesium strip into each beaker, and observe. Record your observations.
4. Clean up and put away the equipment you have used.

Demonstration 2 Combustion of Flour

5. Roll a sheet of aluminum foil into a tube, and tape the edges together.
6. Measure about 30 mL of sifted flour into a small plastic bowl.
7. Light a candle and hold the aluminum tube above it. Drop the flour into the tube from the top by pouring it through a sifter held above the tub. Observe. Record your observations.
8. Clean up and put away the equipment you have used.

Demonstration 3 Decomposition of Hydrogen Peroxide

9. Place a 200 mL graduated cylinder into a plastic pan (to catch any spills).
10. Add about 1 mL of soap and a few drops of food colouring to a 200 mL graduated cylinder.
11. Add about 1 mL of potassium iodide (KI) powder to the mixture.
12. Add 20 mL of hydrogen peroxide solution ($H_2O_2(aq)$) to the mixture. Observe. Record your observations.
13. Light a wooden splint. Extinguish the flame, then plunge the glowing splint into the soap bubbles that have been produced. Observe. Record your observations.
14. Clean up and put away the equipment you have used.

What Did You Find Out?

Discuss the following as a class.

1. What is the connection between the concentration of a reactant and the rate of the chemical reaction?
2. (a) What factor was responsible for increasing the rate of combustion of flour?
   (b) What are several real world situations where this factor might apply to reactions?
3. (a) What factor was responsible for speeding up the decomposition of hydrogen peroxide?
   (b) Most chemical reactions in your body are sped up in this fashion. What is the biological term for the kind of substance that speeds up reactions in living things?

Did You Know?

The tusks, some hair, and some skin of this Siberian woolly mammoth were preserved by cold temperatures and dry air for 23 000 years before being discovered in 1997.

Temperature

One way chemists control the rate of a chemical reaction is by controlling the temperature. For example, when you cook food, you use heat to increase the rate of reactions that cause the breakdown of food into simple components. When you refrigerate food, you remove heat and lower the rate of reactions that cause food to spoil.

You can see the effect of a change in temperature on reaction rate in the operation of light sticks. The light produced by light sticks is the result of a chemical reaction that begins when you bend the light stick and crack open a container inside it. This allows the reactants to mix and begin generating light. As you can see in Figure 6.13, temperature affects the rate of reaction and the brightness of the light. When placed in hot water, light sticks glow more brightly, but they also glow for a shorter period of time because the reactants are used up more quickly than at a cooler temperature.

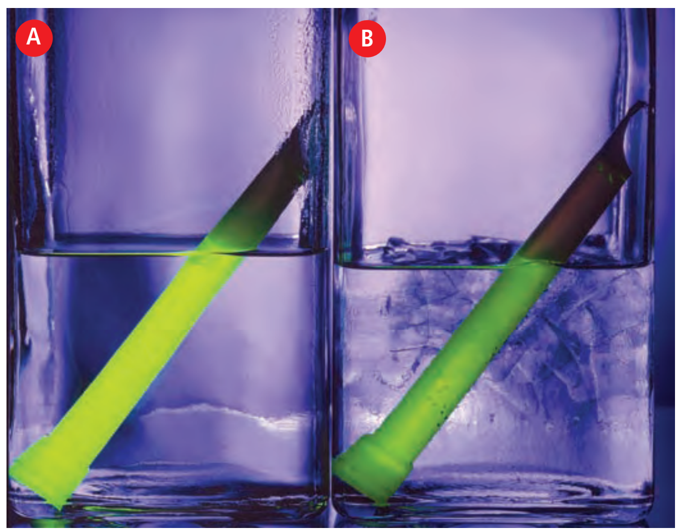

Figure 6.13 The chemical reaction rate is higher in the hot water than in the cold water. Therefore, the light stick in hot water (A) glows more brightly than the one in cold water (B).

Why does temperature affect reaction rate? Heating causes the particles (atoms or molecules) of the reactants to move more quickly, resulting in more collisions and more energy. Lowering the temperature slows down the particles of the reactants so that they collide with each other less frequently and with less energy.

Reading Check

1. Heating a light stick can make it glow brighter. Why?
2. What happens to the rate of a chemical reaction when the temperature is raised?
3. What does cooling do to the frequency at which particles of reactants can collide?
4. How does cooling affect the energy of the collisions between particles?

Concentration

Another way chemists can change the rate of a reaction is by changing the concentrations of the reactants. Concentration refers to how much solute is dissolved in a solution. We measure concentration by knowing the mass of a substance that is in 1 L of the solution. In order for new substances to be formed, the reactant atoms and molecules must be able to make contact with each other. If there is a greater concentration of reactant atoms and molecules present, there is a greater chance that collisions among them will occur. More collisions mean a higher reaction rate (Figure 6.14). Increasing the concentration of the reactants usually results in a higher reaction rate.

Figure 6.14 When you blow on a campfire, you are increasing the concentration of oxygen near the flames. Your exhaled breath has more oxygen than the air near the flames.

The concentration of a substance can change if it is in aqueous solution or in the gas state. For example, dilute hydrochloric acid will react more slowly with zinc than will concentrated hydrochloric acid (Figure 6.15). At lower concentrations, there is less chance for molecules of hydrochloric acid to make contact with the molecules of the zinc surface. Decreasing the concentrations of the reactants results in a lower reaction rate.

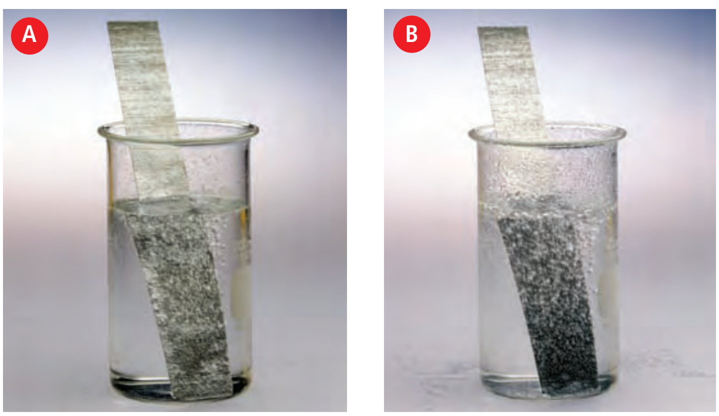

Figure 6.15 Hydrochloric acid reacts at a slower rate with zinc when the acid is less concentrated (A). The reaction rate is much faster when the acid is more concentrated (B).

We can identify oxygen gas by inserting a glowing wooden splint into a small container of the gas. If the splint bursts into flame, a high concentration of oxygen is present. In air, the splint only glows. The splint does not burst into flame because the concentration of oxygen in the air is only about 21 percent. There are not enough collisions among the oxygen molecules in air and the wooden splint to support a rapid combustion reaction. In a high concentration of oxygen, however, the increased number of collisions between oxygen molecules and the splint cause the flame to burn brightly. Figure 6.16 shows another example of the increased reaction rate when the concentration of a reactant is increased.

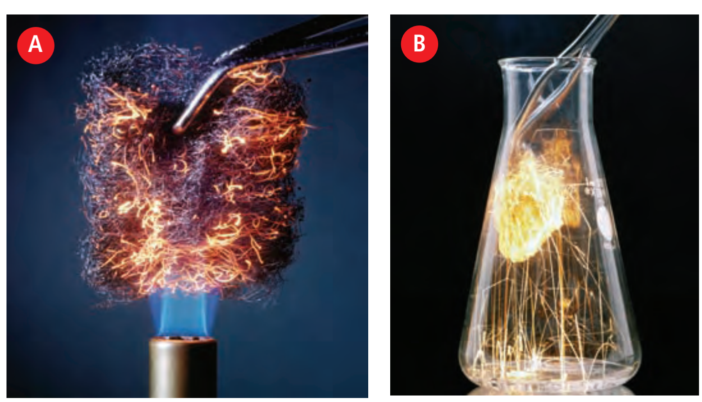

Figure 6.16 The concentration of oxygen in the air surrounding the steel wool is much less than that of the pure oxygen in the flask (A). The higher oxygen concentration in the flask accounts for the higher reaction (B).

Figure 6.17 The rate at which the nylon is produced is controlled by limiting the surface area where the reactants in each layer can make contact.

Surface Area

Suppose you lowered a red-hot piece of steel into a flask of oxygen gas and the same mass of red-hot steel wool into another flask of oxygen gas. What might be different? The oxygen would react with the chunk of steel much more slowly than it would with the steel wool. Can you explain why? For the same mass of iron, steel wool has more surface area than the chunk of steel. **Surface area** is the measure of how much area of an object is exposed. The greater surface area of the steel wool allows oxygen molecules to collide with many more iron atoms per unit of time. For the same mass, many small particles have more total surface area than one large particle. Powders have much more surface area than solid blocks made of the same material. Powders may need to be stirred or blown into the air (as in a dust explosion) before the increase in reaction rate is noticed.

Surface area can also be important if the reaction occurs between two liquids that cannot mix. In this case, the reaction can occur only at the boundary where the two liquids meet. For example, in order to make nylon, one component is dissolved in water and the other component is dissolved in an organic solvent such as tetrachloromethane. Because organic solvents and water do not mix very well, the two reactants only react at the surface where the solutions meet. This use of surface area to control the rate of the reaction allows a long thin fibre to form (Figure 6.17). Without this control, a solid block of nylon would form in the beaker. Not all reactions depend on surface area. If both reactants are gases or are liquids that mix together, then there is no surface, and surface area is not a factor.

Did You Know?

Substances called inhibitors are used to slow down a chemical reaction. For example, food preservatives such as BHT and BHA may provide chemical reactions for removing oxygen from the food. A decreased concentration of oxygen results in a slower reaction rate. Some inhibitors prevent a reaction from happening at all.

Reading Check

1. How does increasing concentration result in an increase in reaction rate?
2. Can the concentration of a substance change if it is a gas?
3. Can the concentration of a solution change if it is an aqueous solution?
4. How does increasing the surface area of a reactant increase reaction rate?

Presence of a Catalyst

The temperature and the concentration of reactants affect the rate of a reaction. However, increasing temperature or concentration is not always the best or most practical thing to do. For example, suppose that you want to increase the rate of the decomposition of glucose in a living cell. Increasing the temperature or the concentration of reactants is not an option because doing so might harm the cell. In this case, it may be helpful to use a catalyst. A **catalyst** is a substance that speeds up the rate of a chemical reaction without being used up in the reaction itself. A catalyst generally is not included directly when we write the chemical equation of a reaction.

Your body contains thousands of different biological catalysts, called enzymes (Figure 6.18). Enzymes are large organic molecules, usually proteins, which speed up reactions in living cells. Each enzyme in your body is specialized to perform its own function. For example, saliva contains an enzyme called amylase that breaks down only starch molecules. A large set of enzymes digests carbohydrates, fats, and protein molecules. Another complex set of enzymes makes new DNA. Still other enzymes convert extra nutrients into fat for storage. Many chemical reactions in living organisms would not occur quickly enough to sustain life at normal temperatures if it were not for the presence of enzymes. Like all catalysts, enzymes are not changed or used up by the reactions in which they are involved.

How do catalysts speed up reactions? Energy is needed to break bonds in any chemical reaction. One way to increase the rate of a reaction involves lowering the bond-breaking energy. Catalysts make it possible for reactions to occur with less energy than reactions would otherwise need to break old chemical bonds and form new ones. In the presence of a catalyst, molecules of reactants line up better so that when they collide with each other the reaction is more likely to take place.

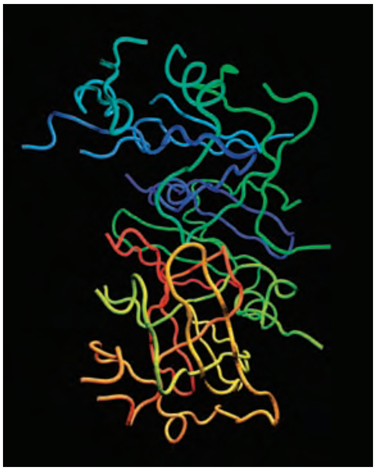

Figure 6.18 Enzymes are biological catalysts. The enzyme shown here, called TIM, helps convert glucose in your body into other kinds of molecules. During this process, energy is released for your body to use.

Catalytic converters

All automobiles built in North America since the 1980s have pollution control devices built into their exhaust systems (Figure 6.19). A **catalytic converter** is a stainless steel device, shaped like a muffler, located underneath the frame of the vehicle. Inside it is a ceramic or wire honeycomb-like structure that provides a large surface area for reactions to take place. The surface of the honeycomb is coated with a thin layer of metallic catalysts, involving platinum, rhodium, and palladium.

As exhaust passes through the catalytic converter, several reactions occur. Much of the poisonous carbon monoxide, which is produced from the combustion of gasoline, reacts with oxygen and is changed into carbon dioxide. Hydrocarbons react with oxygen to produce carbon dioxide and water. Finally, most of the poisonous nitrogen oxides are converted into nitrogen gas and oxygen gas in the following reaction.

$$2N_2O_3 \rightarrow 2N_2 + 3O_2$$

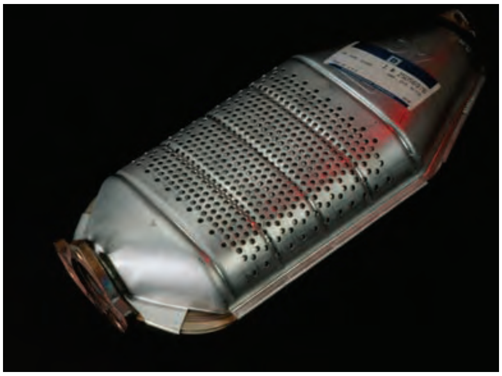

Figure 6.19 Most catalytic converters work best when the catalysts are warmed up. Studies show that 70 percent of all pollutants released from a car happen during the first 90 s while the car warms up. Very little pollution is produced after the first 90 s.

Suggested Activity

Conduct an Investigation 6-2B on page 278.

Explore More

Foods often spoil because they react with oxygen. Many methods of food preservation maintain product freshness by excluding oxygen. For example, crackers and popcorn are often packaged in an atmosphere of an unreactive gas such as nitrogen or argon.
Find out more about chemical reactions and food preservation.
Start your search at **www.bcscience10.ca.**

6-2B Factors Affecting Reaction Rate

Skill Check

- Observing
- Predicting
- Measuring
- Controlling variables

Safety

- Wear safety goggles and protective clothing.
- Avoid touching all reactants and products.
- Do not remove any materials from the science room.
- Never taste or eat anything in the science room.
- Follow your teacher's directions for safety in the science room.
- Wash your hands and equipment thoroughly after completing this activity.

In this activity, you will investigate temperature, surface area, and presence of a catalyst as factors affecting the rate of a reaction.

Question

How do temperature, surface area, and the presence of a catalyst affect the rate of a chemical reaction?

Materials

Part 1

- two 400 mL beakers
- ice water
- hot water
- thermometer
- 3 effervescent tablets
- stopwatch

Part 2

- 3 small test tubes
- test tube rack
- dish soap
- 6% hydrogen peroxide solution (H_2O_2)
- potassium iodide (KI)
- copper(II) chloride ($CuCl_2$)
- sodium chloride (NaCl)

Part 3

- mortar and pestle
- sodium carbonate
- 4 small test tubes
- test tube rack
- dilute hydrochloric acid solution (HCl)

Procedure

Part 1 Effect of Temperature

1. Fill one beaker with ice water. Fill the second beaker with very hot water. Use a thermometer to measure the temperature in each beaker. Record the temperatures.
2. Drop an effervescent tablet into each beaker at the same time. Observe. Use a stopwatch to measure how many seconds it takes for each tablet to finish dissolving. Record the times. Dispose of beaker contents down the sink.

3. Fill one of the beakers with a mixture of hot water and ice water. Adjust the temperature by adding more warm or cool water until the temperature is halfway between the temperatures recorded in step 1.
4. Make a prediction of the length of time it will take for an effervescent tablet to finish dissolving. Record your prediction.
5. Add a tablet to the water that is at a middle temperature. Observe and record the time it takes to dissolve. Dispose of beaker contents down the sink.

Part 2 Effect of Adding a Catalyst

6. Label three test tubes: KI, $CuCl_2$, NaCl. Place the test tubes in the test tube rack.
7. Place one drop of dish soap into each test tube.
8. Into each test tube, pour 6% hydrogen peroxide to a depth of about 2 cm.
9. Add a pea-sized amount of solid KI, $CuCl_2$, and NaCl to the appropriate test tube. Observe. Record your observations, including which reaction rate is the fastest and which is the slowest.
10. Dispose of test tube contents as your teacher directs.

Part 3 Effect of Surface Area

11. Use the pestle to grind some sodium carbonate lumps into a fine powder in the mortar. Place the four test tubes in the test tube rack.
12. Place lumps of sodium carbonate into one of the test tubes to a depth of about 1 cm. Place some finely ground sodium carbonate into a second test tube to a depth of about 1 cm.
13. Measure dilute hydrochloric acid solution into the two remaining test tubes to a depth of about 2 cm.
14. Simultaneously, pour the dilute HCl solution into each of the test tubes containing sodium carbonate. Observe. Note which reaction was faster.
15. Clean up and put away the equipment you have used. Follow your teacher's instructions for disposal of wastes.

Analyze

1. What is the relationship between rate of reaction and change in temperature?
2. Compare your prediction in step 4 of the length of time it would take an effervescent table to dissolve at the middle temperature with how long it actually took.
3. (a) Which of the solutions that were added to the hydrogen peroxide solution may have acted as a catalyst?
   (b) Which catalyst sped up the reaction the most?
4. Which has more surface area, a 5 g lump of sodium carbonate or 5 g of sodium carbonate powder?
5. How did surface area affect the rate of sodium carbonate decomposition in step 14?

Conclude and Apply

1. Suppose a reaction involved a finely ground powder reacting with a concentrated acid. Suggest three methods of decreasing the reaction rate.

Science Watch

Testing an air bag

Manufacturing air bags

Reaction Rate in Air Bags

Impact! Within 27 ms (0.027 s), a nylon air bag inflates. Another 23 ms later, the driver narrowly escapes serious injury, perhaps even death. Air bags are now a required feature of all new cars and trucks. Research shows that deaths among drivers using air bags and seatbelts are 26 percent lower than when using seatbelts alone.

Air bags dramatically illustrate the need for careful, precise control of chemical reactions. Vehicle air bags contain a compound called sodium azide, NaN_3, in the form of pellets. By carefully determining and controlling the surface area, a precise amount of gas is released at a highly specific rate. What might be the consequences if engineers could not control this reaction?

The air bag needs to inflate quickly enough to provide impact protection. But that is not all. The air bag needs to be partly deflated before the driver or passenger makes contact with it. Hitting the bag at maximum inflation would be just as dangerous as hitting an unprotected dashboard or steering wheel.

The shape of the sodium azide pellets allows engineers to determine the precise surface area needed for a reaction to occur within a very specific period of time, measured in milliseconds. If a front-end collision occurs, an electric signal ignites the sodium azide. The compound quickly decomposes, releasing 60 L of nitrogen gas to inflate the bag.

The chemical equation for the decomposition reaction of sodium azide is:

$$2NaN_3(s) \rightarrow 2Na(s) + 3N_2(g)$$

If the sodium that results from the reaction were to come in contact with moisture—for example, from a person's mouth or eyes—caustic sodium hydroxide would form. To prevent this, designers include other components, such as aluminum silicate, silicon dioxide, or alumina in the air bag. These components react with the sodium to form non-toxic sodium silicate, a form of sand, which is unreactive and safe.

Questions

1. What are the negative effects of an air bag inflating or deflating too slowly?
2. What does controlling the surface area of the sodium azide pellets have to do with the operation of air bags?
3. The decomposition of NaN_3 produces nitrogen gas, which inflates the air bag, as well as sodium metal.
   (a) What are the harmful effects of sodium metal?
   (b) How is sodium metal removed from the air bag during inflation?

Check Your Understanding

Checking Concepts

1. Give three examples where it is helpful to have a high reaction rate.
2. Give three examples where it is helpful to have a low reaction rate.
3. What is the function of enzymes?
4. What usually happens to the rate of a reaction when the concentration of one of the reactants is increased?
5. Which has a greater surface area, a single sugar cube or a spoonful of sugar? Explain your answer.
6. How does surface area affect the rate of a reaction?
7. Give an example of a reaction where surface area is not a factor.
8. How does a catalyst speed up a chemical reaction?

Understanding Key Ideas

9. The various factors that affect the rate of a reaction work in different ways at the molecular level. Raising temperature causes molecules to move more quickly, allowing them to hit each other harder and more often. Raising the concentration puts more molecules into the system than were present before. Adding a catalyst helps the molecules to hit with better alignment, making the formation of product more likely.
   (a) Which of these factors increase the reaction rate by increasing the number of collisions between reacting molecules?
   (b) Which of these factors work by making the collisions between the molecules happen in a more effective way?
   (c) Do any of these factors do both?
10. Explain how raising the temperature increases the rate of a chemical reaction.
11. Explain why increasing the surface area in a reaction will increase the rate of the reaction.
12. Explain why increasing the concentration of a reactant will increase the rate of a reaction.
13. Explain how using a catalyst makes it possible for the reaction to happen with less energy than without the catalyst.

Pause and Reflect

Suppose you have a box full of wrapped chocolates. Whenever you unwrap a chocolate to eat it, you throw the wrapper back into the box.

(a) What will happen to your rate of chocolate eating as time goes on?

(b) Why will it change?

(c) How might this analogy apply to the rate of a chemical reaction in terms of a catalyst (you) and concentration of reactants?

Chapter Review

Prepare Your Own Summary

In this chapter, you learned to classify reactions as one of six different types as well as predict the identity of the products of the reaction. You investigated the factors that affect the rate of chemical reaction and examined the role of catalysts in reaction rate. Create your own summary of the key ideas from this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 11 for help with graphic organizers.) Use the following headings to organize your notes:

1. Six Types of Chemical Reactions
2. Classifying and Predicting Products of Reactions Based on the Reactants Only
3. Examples of Reactions Occurring at Different Rates
4. Four Factors Affecting the Rates of Reactions.

Checking Concepts

1. Identify each of the following reactions as synthesis, decomposition, single replacement, double replacement, neutralization (acid-base), or combustion.
   (a) $H_3PO_4 + 3NaOH \rightarrow Na_3PO_4 + 3H_2O$
   (b) $P_4 + 5O_2 \rightarrow P_4O_{10}$
   (c) $2Al + N_2 \rightarrow 2AlN$
   (d) $2HBr \rightarrow H_2 + Br_2$
   (e) $HF + KOH \rightarrow KF + H_2O$
   (f) $Au(NO_3)_3 + 3KI \rightarrow AuI_3 + 3KNO_3$
   (g) $Mg + 2\ HCl \rightarrow MgCl_2 + H_2$
   (h) $2Ti(NO_3)_3 + 3Cu \rightarrow 2Ti + 3Cu(NO_3)_2$
   (i) $(NH_4)_2CO_3 + Mn(NO_3)_2 \rightarrow 2NH_4NO_3 + MnCO_3$
   (j) $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$
2. Each reaction below has been identified by type. Use this information to help predict products. Copy and then complete each equation by writing the products of the reactions. **Hint:** Use the charges shown on the periodic table in Figure 4.3 on page 172. Remember to include subscripts and parentheses when required.
   (a) $Al + F_2 \rightarrow$ synthesis
   (b) $K + O_2 \rightarrow$ synthesis
   (c) $C_2H_6 + O_2 \rightarrow$ combustion
   (d) $C_6H_{12}O_4 + O_2 \rightarrow$ combustion
   (e) $Rb_2O \rightarrow$ decomposition
   (f) $SrF_2 \rightarrow$ decomposition
   (g) $BaCl_2 + Pb(NO_3)_2 \rightarrow$ double replacement
   (h) $AgNO_3 + K_2Cr_2O_7 \rightarrow$ double replacement
   (i) $Br_2 + NiI_3 \rightarrow$ single replacement, element is a non-metal
   (j) $Cl_2 + Mg_3N_2 \rightarrow$ single replacement, element is a non-metal
   (k) $HCl + Mo(OH)_2 \rightarrow$ neutralization (acid-base)
   (l) $Sn(OH)_2 + HClO_3 \rightarrow$ neutralization (acid-base)
   (m) $Al + CuI_2 \rightarrow$ single replacement, element is a metal
   (n) $Mg + FeF_2 \rightarrow$ single replacement, element is a metal
3. Which type(s) of reactions match the following descriptions?
   (a) There is only one reactant.
   (b) There is only one product.
   (c) The reactants are an acid and a base.
   (d) The products are an element and a compound.
   (e) The products are carbon dioxide and water.
   (f) Both reactants are compounds.
   (g) One reactant is an element. The other is a compound.

4. Which of the four factors affecting reaction rate is most important in each example below? Choose from among concentration, temperature, surface area, and catalyst.
   (a) Extra dish soap is added to help cut the grease when washing a frying pan.
   (b) Firewood is chopped up into kindling (small pieces) to help start a fire.
   (c) A lighted match is brought near a candlewick in order to light the candle.
   (d) Lemon juice is rubbed on an iron sink to help remove rust.
   (e) The accelerator pedal in a car is pressed, resulting in a faster consumption of fuel in the engine.
   (f) The reaction of oxygen with sucrose in human cells takes place in the presence of an enzyme.
   (g) In order to release the fragrance of garlic when frying it in oil, the garlic is crushed and ground.
   (h) A mild skin disinfectant containing hydrogen peroxide is prepared in a 1 percent solution, while a stronger formulation is prepared in a 3 percent solution.

Understanding Key Ideas

5. Classify each of the following reactions, and write a balanced formula equation for each.
   (a) lithium + oxygen ➔ lithium oxide
   (b) magnesium + aluminum chloride ➔ magnesium chloride + aluminum
   (c) butane (C_4H_{10}) + oxygen ➔ carbon dioxide + water
   (d) hydrochloric acid + lithium hydroxide ➔ lithium chloride + water
   (e) aluminum oxide ➔ aluminum + oxygen
   (f) tin + gold(III) nitrate ➔ tin(IV) nitrate + gold
   (g) barium hydroxide + lead((IV) bromide ➔ barium bromide + lead(IV) hydroxide
   (h) glycerine ($C_3H_8O_3$) + oxygen ➔ carbon dioxide + water
   (i) nitrogen + oxygen ➔ nitrogen dioxide
6. Some chemical reactions are affected by surface area, whereas others are not. Explain why this is so.

Applying Your Understanding

7. Suppose a chemist performed an experiment dissolving equal masses of marble in hydrochloric acid. The results of the three trials are shown in the table below.

Trial	Hydrochloric Acid	Marble	Temperature
1.	Dilute	Finely ground	20°C
2.	Concentrated	Lump	20°C
3.	Dilute	Lump	40°C

The marble dissolved fastest in Trial 1. and slowest in Trial 2. List concentration, surface area, and temperature in decreasing order of their importance in increasing the rate of this reaction.

Pause and Reflect

Many chemical reactions happen in your daily life. When might it be important for you to use your knowledge of speeding up or slowing down chemical reactions? How could you use your knowledge?