Chapter 6

Chemical Reactions

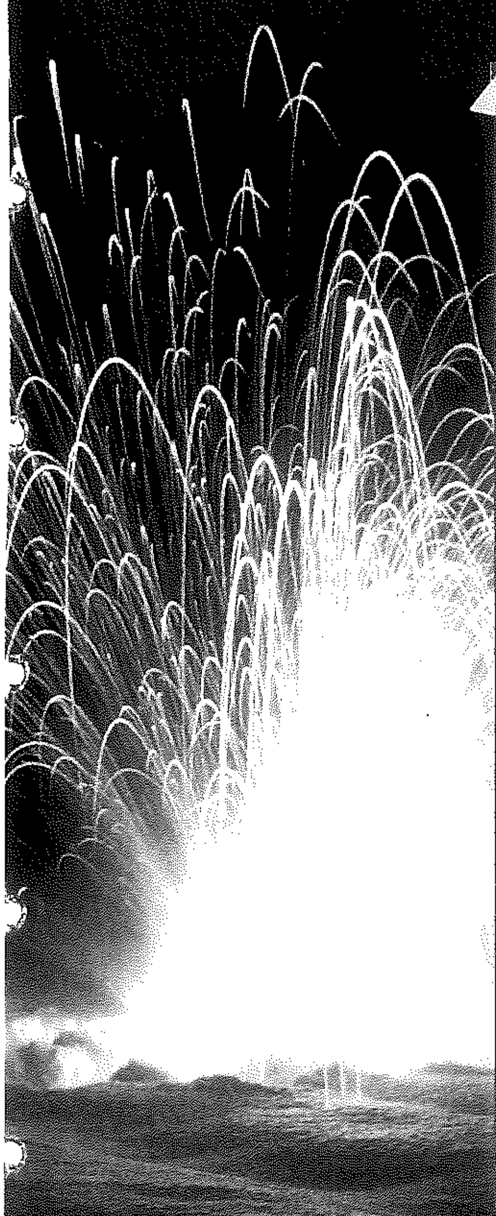
The BIG Idea

Chemical Changes in Matter

What happens during a chemical reaction?

Chapter Preview

Sparks fly as sodium metal reacts with water.



Lab zone™ Chapter **Project**

Design and Build a Closed Reaction Chamber

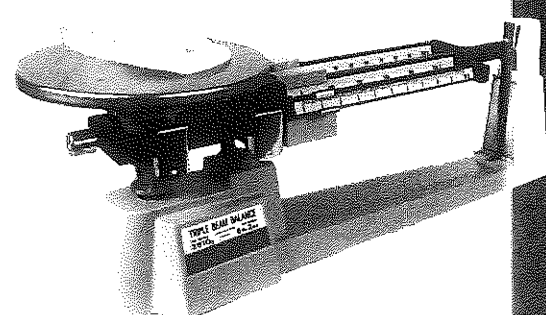
When water evaporates, it is not destroyed or lost. In fact, matter is never created or destroyed in either a physical change or a chemical reaction. In this chapter project, you will design and build a closed structure in which a chemical reaction can occur. You will use the chamber to confirm that matter is not created or destroyed in a chemical reaction.

Your Goal To design and build a closed chamber in which sugar can be broken down

Your structure must

- be made of materials that are approved by your teacher
- be built to specifications agreed upon by the class
- be a closed system so the masses of the reactants and products can be measured
- be built following the safety guidelines in Appendix A

Plan It! Before you design your reaction chamber, find out how sugar can be broken down. Next, brainstorm with classmates to determine the safety features of your chamber. Then choose materials for your structure and sketch your design. When your teacher has approved your design, build and test your structure.



Section 1

Observing Chemical Change

Reading Preview

Key Concepts

- How can matter and changes in matter be described?
- How can you tell when a chemical reaction occurs?

Key Terms

- matter • chemistry
- physical property
- chemical property
- physical change
- chemical reaction • precipitate
- endothermic reaction
- exothermic reaction

Target Reading Skill

Asking Questions Before you read, preview the red headings. In a graphic organizer like the one below, ask a *what* or *how* question for each heading. As you read, write the answers to your questions.

Properties and Changes of Matter

Question	Answer
What are physical properties of matter?	Physical properties are . . .

Lab zone Discover Activity

What Happens When Chemicals React?

1. Put on your safety goggles. Place 2 small spoonfuls of baking soda into a clear plastic cup.
2. Holding the cup over a large bowl or sink, add about 125 mL of vinegar. Swirl the cup gently.
3. Look at the material in the cup. What changes do you see? Feel the outside of the cup. What do you notice about the temperature?
4. Carefully fan the air above the liquid toward you. What do you smell?

Think It Over

Observing What changes did you detect using your senses of smell and touch?

Picture yourself toasting marshmallows over a campfire. You see the burning logs change from a hard solid to a soft pile of ash. You hear popping and hissing sounds from the fire as the wood burns. You smell smoke. You feel the heat on your skin. Finally, you taste the results. The crisp brown surface of the toasted marshmallow tastes quite different from the soft white surface of a marshmallow just out of its bag. Firewood, skin, and marshmallows are all examples of matter. **Matter** is anything that has mass and takes up space. The study of matter and how matter changes is called **chemistry.**

Chemical change can lead to a treat. ▶

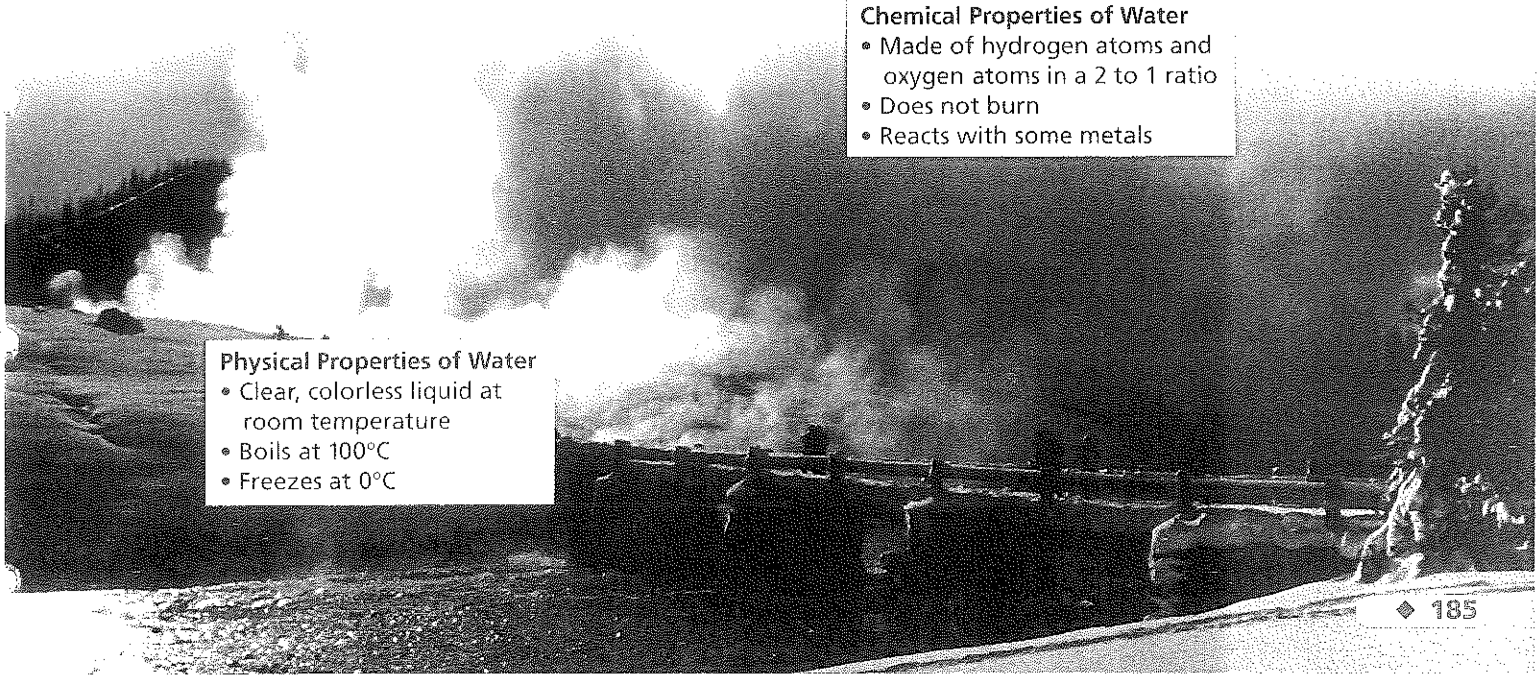
Properties and Changes of Matter

Part of studying matter is describing it. When you describe matter, you explain its characteristics, or properties, and how it changes. **Matter can be described in terms of two kinds of properties—physical properties and chemical properties. Changes in matter can be described in terms of physical changes and chemical changes.**

Properties of Matter A **physical property** is a characteristic of a substance that can be observed without changing the substance into another substance. The temperature at which a solid melts is a physical property. For example, ice melts at a temperature of zero degrees Celsius. Color, hardness, texture, shine, and flexibility are some other physical properties of matter. The ability of a substance to dissolve in water and how well it conducts heat and electricity are examples of still more physical properties of matter.

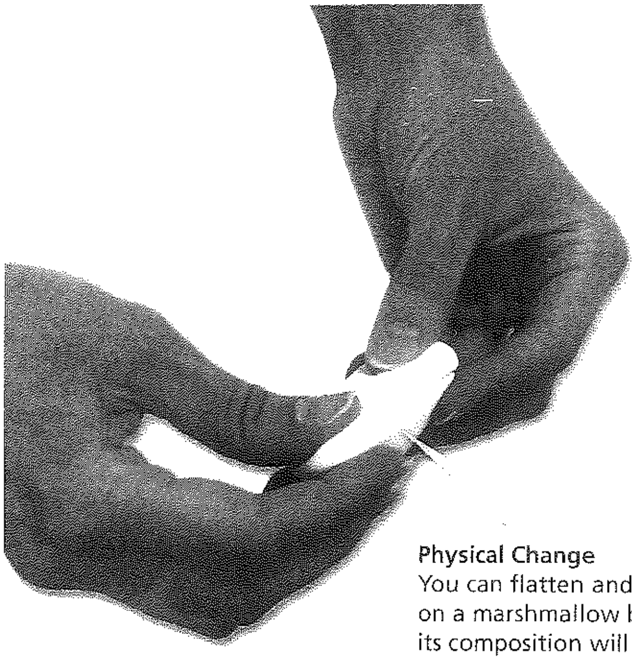
A **chemical property** is a characteristic of a substance that describes its ability to change into other substances. To observe the chemical properties of a substance, you must change it to another substance. For example, when magnesium burns, it combines with oxygen in the air, forming a new substance called magnesium oxide. People who make objects out of magnesium must be careful because the metal can catch fire. Burning is only one type of chemical property. Other examples of chemical properties are tarnishing and rusting.

FIGURE 1
Properties of Water
This geyser gives off hot water and water vapor, which condenses into a visible cloud in the cold air. The temperatures at which water boils and freezes are physical properties of water.
Predicting *How will the snow change when spring arrives?*



Chemical Properties of Water
- Made of hydrogen atoms and oxygen atoms in a 2 to 1 ratio
- Does not burn
- Reacts with some metals

Physical Properties of Water
- Clear, colorless liquid at room temperature
- Boils at 100°C
- Freezes at 0°C



Physical Change
You can flatten and pull on a marshmallow but its composition will stay the same.

Chemical Change
If you toast a marshmallow, the sugars and other substances will cook or burn, producing a crust made of new substances.

FIGURE 2
Changes in Matter
Matter can undergo both physical change and chemical change.

Lab zone Skills Activity

Classifying

Classify each of the following changes as either a chemical change or a physical change. Explain your reasoning for each case.

- A piece of metal is heated to a high temperature and changes to a liquid.
- When two solutions are poured into the same container, a powdery solid forms and settles to the bottom.
- Water left in a dish overnight has disappeared by the next day.
- A blacksmith hammers a piece of red-hot iron into the shape of a knife blade.

Changes of Matter You probably have seen solid water (ice) change to liquid water. Water is the same substance, whether it is frozen or liquid. Therefore, changing from a solid to a liquid is a physical change. A **physical change** is any change that alters the form or appearance of a substance but that does not make the substance into another substance. You cause a physical change when you squash a marshmallow. The shape of the marshmallow changes but not the taste! It's still made of the same compounds that have the same properties. Other examples of physical changes are bending, crushing, breaking, cutting, and anything else that changes only the shape or form of matter. Braiding your hair is another example of a physical change.

Sometimes when a change occurs in a substance, the substance itself is changed. For example, the brown crust on a toasted marshmallow is the result of sugar changing to different substances in a mixture called caramel. A change in matter that produces one or more new substances is a chemical change, or **chemical reaction.** The burning of gasoline in a car's engine is a chemical change. The new substances formed end up as the car's exhaust.

Reading Checkpoint **What kind of change occurs when you toast the outside of a marshmallow?**

Bonding and Chemical Change **Chemical changes occur when bonds break and new bonds form.** As a result, new substances are produced. You may recall that atoms form bonds when they share or transfer electrons. The reaction pictured in Figure 3 involves both the breaking of shared bonds and a transfer of electrons.

Oxygen gas (O_2) in the air consists of molecules made of two oxygen atoms that share electrons. These bonds are broken when oxygen reacts with magnesium metal (Mg). Each magnesium atom transfers two of its electrons to an oxygen atom. The oxygen atom becomes a negative ion, and the magnesium atom becomes a positive ion.

You can probably guess what happens next. You may recall that oppositely charged ions attract. An ionic bond forms between the Mg^{2+} ions and the O^{2-} ions. The ionic compound magnesium oxide (MgO) is produced, and energy is released. Magnesium oxide—a white, crumbly powder—has properties that differ from those of either shiny magnesium or oxygen gas. For example, while magnesium melts at about 650°C, it takes temperatures of more than 2,800°C to melt magnesium oxide!

Go Online
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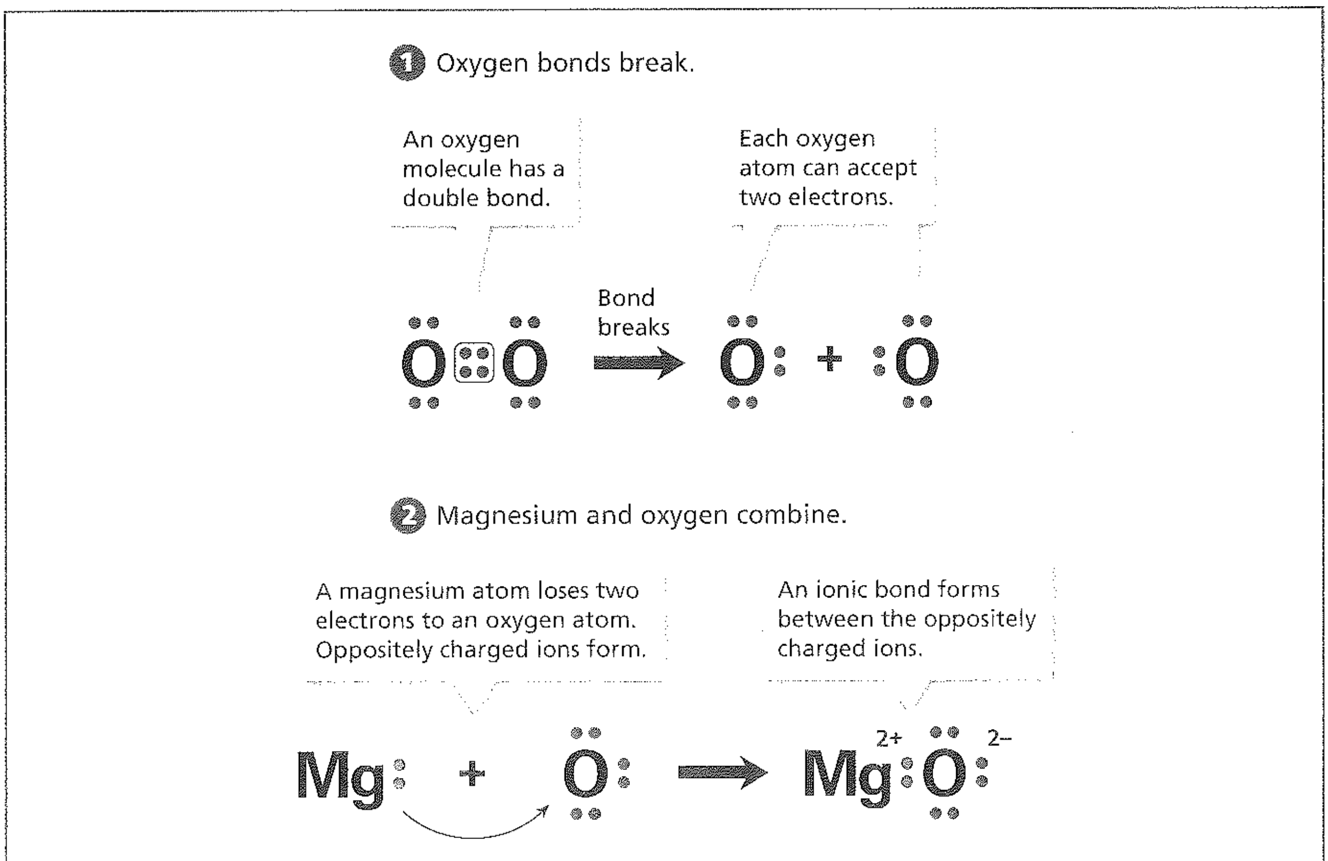
Figure 3
Bonding and Chemical Change
As magnesium burns, bonds between atoms break and new bonds form. The reaction gives off energy. **Interpreting Diagrams** *Why does the oxygen ion have a 2– charge?*



Evidence for Chemical Reactions

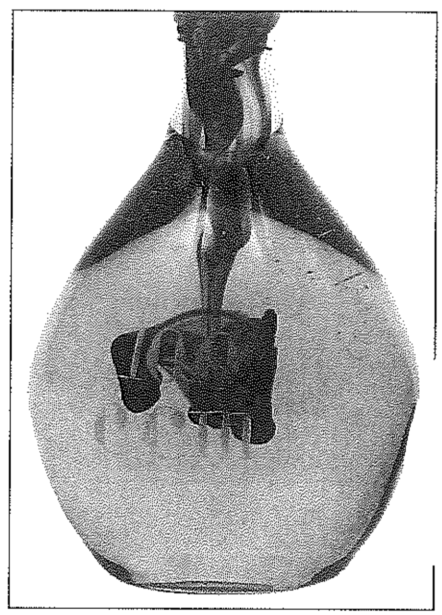
Look at the photograph below of the beaker. Even without reading the caption, you probably could guess it shows a chemical reaction. But how do you know? How can you tell when a chemical reaction occurs? **Chemical reactions involve two main kinds of changes that you can observe—formation of new substances and changes in energy.**

Changes in Properties One way to detect chemical reactions is to observe changes in the properties of the materials involved. Changes in properties result when new substances form. What kinds of changes should you look for? Look at Figure 4. First, a color change may signal that a new substance has formed. Second, a solid may appear when two solutions are mixed. A solid that forms from solution during a chemical reaction is called a **precipitate** (pree SIP uh tayt).

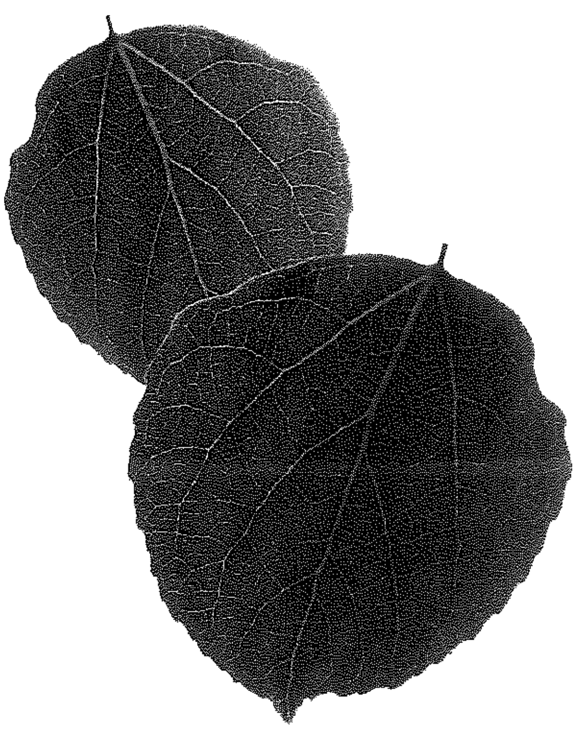
FIGURE 4

Evidence for Chemical Reactions

Many kinds of change provide evidence that a chemical reaction has occurred.
Applying Concepts *What other evidence might tell you a chemical reaction has occurred?*



Two clear liquids react, ▲ forming a precipitate.



◀ The light green leaves of early spring slowly turn darker as chemical reactions in the leaves produce more of the green compound chlorophyll.

Third, a gas might be produced from solids or liquids. If the reaction occurs in a liquid, you may see the gas as bubbles. Finally, other kinds of observable changes in properties can also signal a chemical reaction. For example, moist bread dough forms a dry, porous solid after baking.

Although you may observe a property change in matter, the change does not always indicate that a chemical reaction has taken place. Sometimes physical changes give similar results. For example, when water boils, the gas bubbles you see are made of molecules of water, just as the original liquid was. The sign of a chemical reaction is that one or more new substances are produced. For example, when an electric current is passed through water during electrolysis, two gases are produced, hydrogen gas (H_2) and oxygen gas (O_2).

Reading Checkpoint **How is a precipitate evidence for a chemical reaction?**

Lab zone Try This Activity

Mostly Cloudy

1. Put on your safety goggles and apron.
2. Pour about 5 mL of limewater into a plastic cup.
3. Pour an equal amount of plain water into another plastic cup.
4. Add about 5 mL of carbonated water to each of the cups.

Drawing Conclusions In which cup do you think a chemical reaction occurred? What evidence supports your conclusion?

A golden loaf of bread with its crunchy crust has very different properties from the soft dough that went into the oven. ▼

Oxygen bubbles that form during photosynthesis collect on the leaves of a plant. ▼

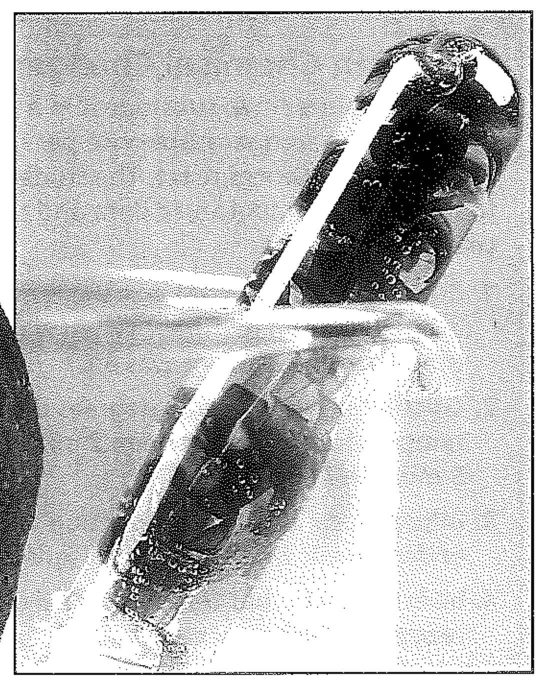
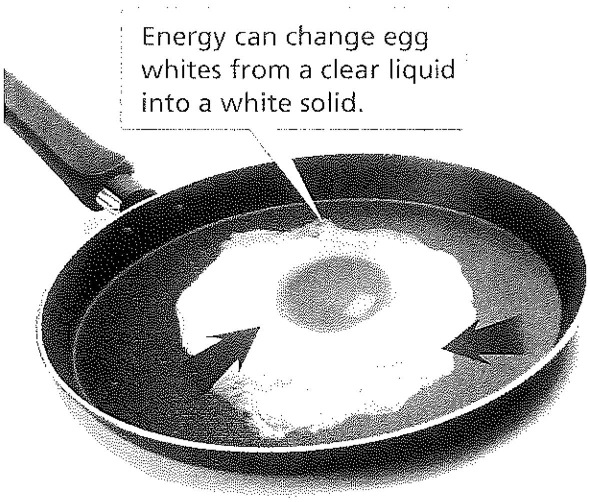


FIGURE 5

An Endothermic Reaction

Energy must be added continuously to fry an egg. Making Generalizations *In terms of energy, what kind of reaction usually occurs when food is cooked?*



Changes in Energy From your everyday experience, you know about various types of energy, such as heat, light, and electricity. As matter changes, it can either absorb or release energy. A change in energy occurs during a chemical reaction. Some reactions absorb energy, while others release energy. One common indication that energy has been absorbed or released is a change in temperature.

If you did the Discover activity, you observed that the mixture became colder. When baking soda (sodium bicarbonate) reacts with vinegar, the reaction takes heat from the solution, making it feel cooler. This kind of reaction is an example of an endothermic reaction. An **endothermic reaction** (en doh THUR mik) is a reaction in which energy is absorbed. However, endothermic reactions do not always result in a decrease in temperature. Many endothermic reactions occur only when heat is constantly added. For example, the reactions that occur when you fry an egg are endothermic.

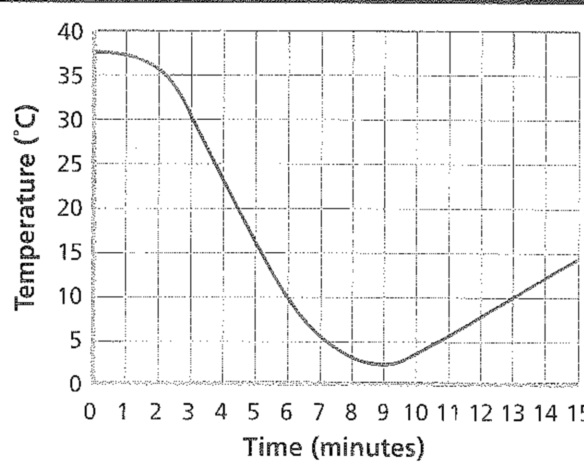
Math Analyzing Data

Energy in Chemical Changes

A student places two substances in a flask and measures the temperature once per minute while the substances react. The student plots the time and temperature data and creates the graph at right.

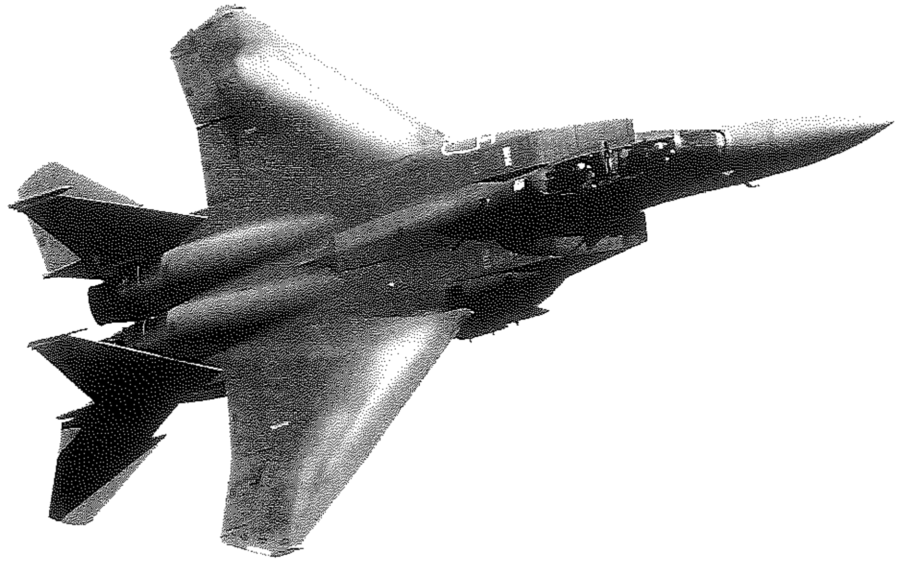
1. Reading Graphs What was the temperature in the flask at 4 minutes? When was the first time the temperature was 6°C?
2. Calculating How many degrees did the temperature drop between 2 minutes and 5 minutes?
3. Interpreting Data Is the reaction endothermic or exothermic? Explain.
4. Inferring At what temperature did the reaction stop? How can you tell?

Energy of a Chemical Reaction



5. Drawing Conclusions Suppose the temperature in the flask increased instead of decreased as the reaction occurred. In terms of energy, what kind of reaction would it be? Explain.

FIGURE 6
An Exothermic Reaction
Enough energy is released by the burning of airplane fuel to keep a plane moving fast enough to fly.



In contrast, the reaction between fuel and oxygen in an airplane engine releases energy, mostly in the form of heat. The heat causes gases in the engine to expand. The expansion and movement of the gases out of the plane exerts a force that moves the plane forward. A reaction that releases energy in the form of heat is called an **exothermic reaction** (ek soh THUR mik). You will learn more about energy and chemical changes in Section 3.

Reading Checkpoint **What is an endothermic reaction?**

Section 1 Assessment

Target Reading Skill Asking Questions Use the answers to questions you wrote about the headings to help you answer the questions below.

Reviewing Key Concepts

1. a. Explaining What is the difference between the physical properties and the chemical properties of a substance?
   b. Posing Questions When silver coins are found in ancient shipwrecks, they are coated with a black crust. What question could you ask to help you decide whether the silver underwent a chemical change or a physical change? Explain.
   c. Making Generalizations In terms of chemical bonds and electrons, what kinds of changes occur between atoms when substances undergo chemical reactions?
2. a. Listing What are five kinds of evidence you can use to determine if a chemical reaction has occurred?
   b. Interpreting Photographs How do the properties of the cooked egg shown in Figure 5 differ from the properties of a raw egg?
   c. Comparing and Contrasting How are endothermic and exothermic reactions the same? How are they different?

Writing in Science

Persuasive Letter Imagine you have a pen pal who is studying chemistry just like you are. Your pen pal claims the change from liquid water to water vapor is a chemical change. Write a brief letter that might convince your pen pal otherwise.

Lab zone **Skills Lab**

Where's the Evidence?

Problem

What are some signs that a chemical reaction has taken place?

Skills Focus

observing, predicting, drawing conclusions

Materials

- 4 small plastic cups
- birthday candles
- 2 plastic spoons
- sugar
- tongs
- clay
- matches
- sodium carbonate (powdered solid)
- graduated cylinder, 10 mL
- aluminum foil, about 10-cm square
- dilute hydrochloric acid in a dropper bottle
- copper sulfate solution
- sodium carbonate solution

Procedure

Preview the steps for each reaction and copy the data table into your notebook.

PART 1

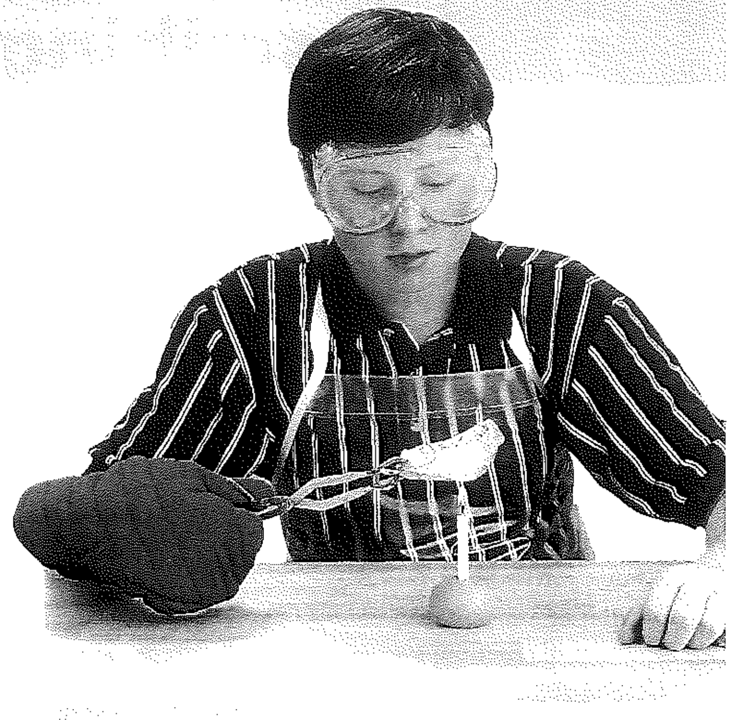
1. Put a pea-sized pile of sodium carbonate into a clean plastic cup. Record in the data table the appearance of the sodium carbonate.
2. Observe a dropper containing hydrochloric acid. Record the appearance of the acid. **CAUTION:** *Hydrochloric acid can burn you or anything else it touches. Wash spills immediately with water.*
3. Make a prediction about how you think the acid and the sodium carbonate will react when mixed. Record your prediction.
4. Add about 10 drops of hydrochloric acid to the sodium carbonate. Swirl to mix the contents of the cup. Record your observations.

PART 2

5. Fold up the sides of the aluminum foil square to make a small tray.
6. Use a plastic spoon to place a pea-sized pile of sugar into the tray.
7. Carefully describe the appearance of the sugar in your data table.

Data Table

Reaction	Observations Before Reaction	Predictions	Observations During Reaction	Observations After Reaction
1. Sodium carbonate (powder) + hydrochloric acid				
2. Sugar + heat				
3. Copper sulfate + sodium carbonate solutions				



8. Secure a small candle on your desktop in a lump of clay. Carefully light the candle with a match only after being instructed to do so by your teacher. **CAUTION:** *Tie back long hair and loose clothing.*
9. Predict what you think will happen if you heat the sugar. Record your prediction.
10. Use tongs to hold the aluminum tray. Heat the sugar slowly by moving the tray gently back and forth over the flame. Make observations while the sugar is heating.
11. When you think there is no longer a chemical reaction occurring, blow out the candle.
12. Allow the tray to cool for a few seconds and set it down on your desk. Record your observations of the material left in the tray.

PART 3

13. Put about 2 mL of copper sulfate solution in one cup. **CAUTION:** *Copper sulfate is poisonous and can stain your skin and clothes. Do not touch it or get it in your mouth.* Put an equal amount of sodium carbonate solution in another cup. Record the appearance of both liquids.
14. Write a prediction of what you think will happen when the two solutions are mixed.
15. Combine the two solutions and record your observations. **CAUTION:** *Dispose of the solutions as directed by your teacher.*
16. Wash your hands when you have finished working.

Analyze and Conclude

1. Predicting How do the results of each reaction compare with your predictions?
2. Observing How did you know when the reaction in Part 1 was over?
3. Interpreting Data What was the evidence of a chemical reaction in Part 1? In Part 2?
4. Drawing Conclusions Was the reaction in Part 2 endothermic or exothermic? Explain.
5. Observing Was the product of the reaction in Part 3 a solid, a liquid, or a gas? How do you know?
6. Drawing Conclusions How do you know if new substances were formed in each reaction?
7. Communicating Make a table or chart briefly describing each chemical change in this lab, followed by the evidence for the chemical change.

More to Explore

Use your observation skills to find evidence of chemical reactions involving foods in your kitchen. Look for production of gases, color changes, and formation of precipitates. Share your findings with your classmates.

Section 2

Describing Chemical Reactions

Reading Preview

Key Concepts

- What information does a chemical equation contain?
- What does the principle of conservation of mass state?
- What must a balanced chemical equation show?
- What are three categories of chemical reactions?

Key Terms

- chemical equation
- reactant • product
- conservation of mass
- open system • closed system
- coefficient • synthesis
- decomposition • replacement

Target Reading Skill

Building Vocabulary Using a word in a sentence helps you think about how best to explain the word. After you read the section, reread the paragraphs that contain definitions of Key Terms. Use all of the information you have learned to write a meaningful sentence using each Key Term.

Lab zone Discover Activity

Do You Lose Anything?

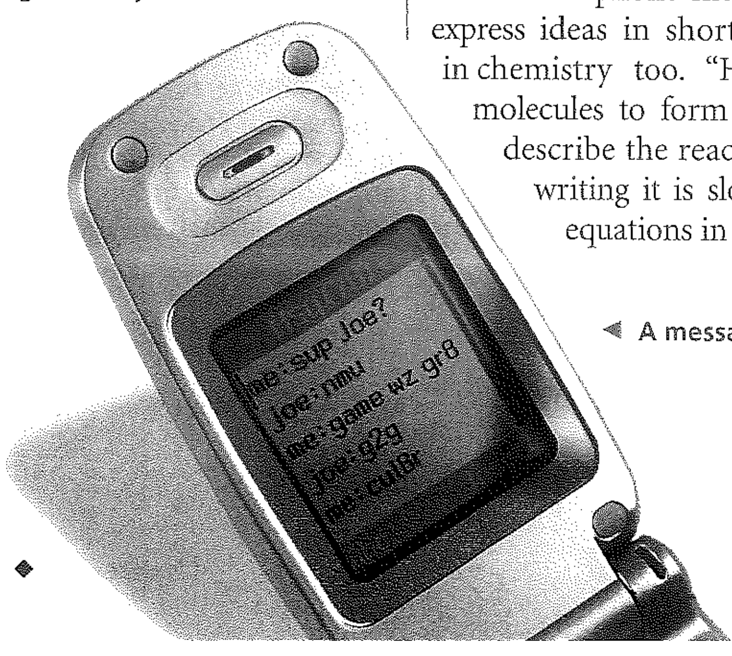
1. Place about two dozen coins on a table. Sort them into stacks of pennies, nickels, dimes, and quarters.
2. Count and record the number of coins in each stack. Calculate and record the value of each stack and the total of all stacks combined.
3. Mix all the coins together and then divide them randomly into four unsorted stacks.
4. Again calculate the value of each stack and the total amount of money. Count the total number of each type of coin.
5. Repeat Steps 3 and 4.

Think It Over

Making Models What happened to the total value and types of coins when you rearranged them? Did rearranging the coins change the properties of any coin? If you think of the coins as each representing a different type of atom, what does this model tell you about chemical reactions?

You look at your cellular phone display and read the message "U wan2 gt pza 2nite?" You reply "No. MaB TPM. CUL8R." These messages are short for saying "Do you want to get some pizza tonight?" and "No. Maybe tomorrow afternoon (P.M.). See you later."

Cellular phone messages use symbols and abbreviations to express ideas in shorter form. A type of shorthand is used in chemistry too. "Hydrogen molecules react with oxygen molecules to form water molecules" is a lengthy way to describe the reaction between hydrogen and oxygen. And writing it is slow. Instead, chemists often use chemical equations in place of words.



◄ A message on a cellular display

What Are Chemical Equations?

A **chemical equation** is a short, easy way to show a chemical reaction, using symbols instead of words. Although chemical equations are shorter than sentences, they contain more information. **Chemical equations use chemical formulas and other symbols instead of words to summarize a reaction.**

Formulas in an Equation All chemical equations use formulas to represent the substances involved in a reaction. You may recall that a chemical formula is a combination of symbols that represents the elements in a compound. For example, CO_2 is the formula for carbon dioxide. The formula tells you that this compound is made up of the elements carbon and oxygen and each molecule has 1 carbon atom and 2 oxygen atoms. Figure 7 lists formulas of other compounds that may be familiar to you.

Structure of an Equation All chemical equations have a common structure. A chemical equation tells you the substances you start with in a reaction and the substances you get at the end. The substances you have at the beginning are called the **reactants.** When the reaction is complete, you have new substances called the **products**.

The formulas for the reactants are written on the left, followed by an arrow. You read the arrow as "yields." The formulas for the products are written on the right. When there are two or more reactants, they are separated by plus signs. In a similar way, plus signs are used to separate two or more products. Below is the general plan for a chemical equation.

Reactant + Reactant ⟶ Product + Product

The number of reactants and products can vary. Some reactions have only one reactant or product. Other reactions have two, three, or more reactants or products. In Figure 8, you can see the equation for a reaction that occurs when limestone ($CaCO_3$) is heated. Count the number of reactants and products, and familiarize yourself with the parts of the equation.

FIGURE 7
The formula of a compound identifies the elements in the compound and the ratios in which their atoms are present.

Formulas of Familiar Compounds

Compound	Formula
Water	H_2O
Carbon dioxide	CO_2
Propane	C_3H_8
Sugar (sucrose)	$C_{12}H_{22}O_{11}$
Rubbing alcohol	C_3H_8O
Ammonia	NH_3
Sodium chloride	$NaCl$
Baking soda	$NaHCO_3$

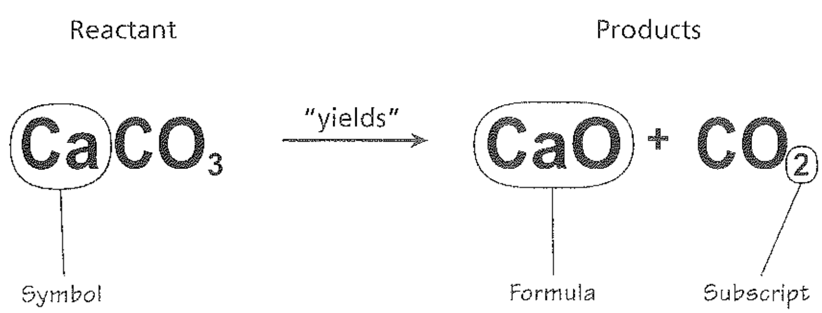


FIGURE 8
A Chemical Equation
Like a building, a chemical equation has a basic structure. Interpreting Diagrams *What does the subscript 3 in the formula for calcium carbonate tell you?*

$$Fe + S \xrightarrow{\Delta} FeS$$

Iron | Sulfur | Iron Sulfide

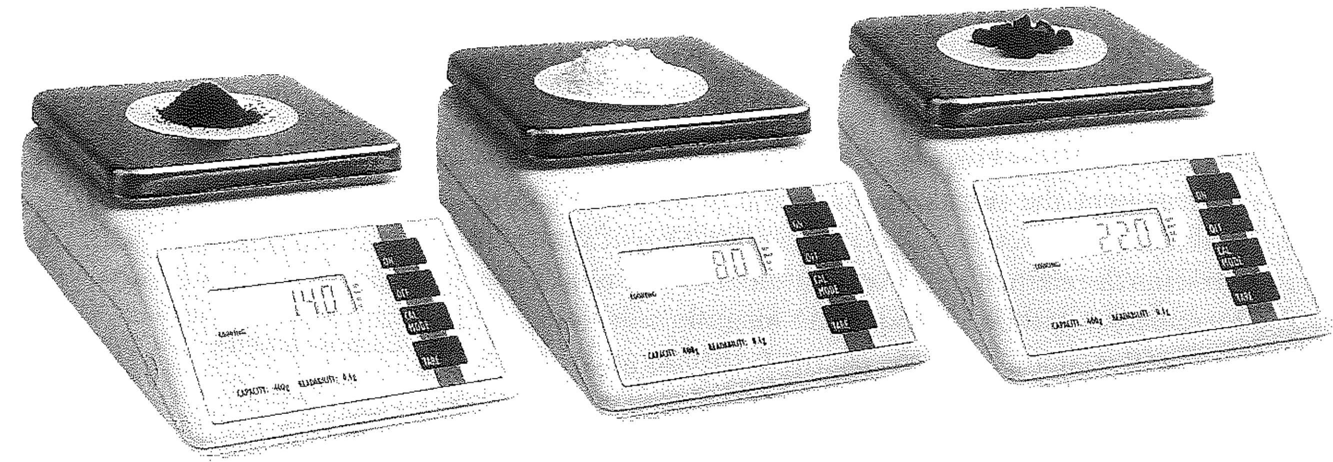


FIGURE 9
Conservation of Mass
Mass is conserved in chemical reactions.

Lab zone Try This Activity

Still There

1. Measure the mass of a collection of bolts, each with a nut attached to it.
2. Remove all the nuts from the bolts. Measure the total mass of the nuts. Then do the same with the bolts. Add these values.
3. Rearrange your collection, putting two or three nuts on one bolt, one nut on another bolt, and so on. You can even leave a few pieces unattached.
4. Measure the total mass again. Compare this figure with the totals from Steps 1 and 2.

Making Models How does your activity model the idea of conservation of mass?

Conservation of Mass

Look closely at the values for mass in Figure 9. Iron and sulfur can react to form iron sulfide. The photograph represents a principle first demonstrated by the French chemist Antoine Lavoisier in 1774. This principle is called **conservation of mass,** and it states that during a chemical reaction, matter is not created or destroyed. All the atoms present at the start of the reaction are present at the end.

Modeling Conservation of Mass Think about what happens when classes change at your school during the day. A class is made of a group of students and a teacher together in a room. When the bell rings, people from each class move from room to room, ending up in different classes. The number of people in the school has not changed. But their arrangement has.

Now imagine that all the students and teachers are atoms, each class is a molecule, and the changing of classes is a chemical reaction. At the end of the reaction, the same atoms are present, but they are grouped together differently. The amount of matter does not change. **The principle of conservation of mass states that in a chemical reaction, the total mass of the reactants must equal the total mass of the products.**

Open and Closed Systems At first glance, some reactions may seem to violate the principle of conservation of mass. It's not always easy to measure all the matter involved in a reaction. For example, if you burn a match, oxygen comes from the surrounding air. But how much? Likewise, the products escape into the air. Again, how much?

A burning match is an example of an open system. In an **open system**, matter can enter from or escape to the surroundings. The burned out fire in Figure 10 is another example of an open system. If you want to measure all the matter before and after a reaction, you have to be able to contain it. In a **closed system**, matter is not allowed to enter or leave. The pear decaying under glass in Figure 10 is a closed system. So is a chemical reaction inside a sealed plastic bag.

Reading Checkpoint **What is a closed system?**

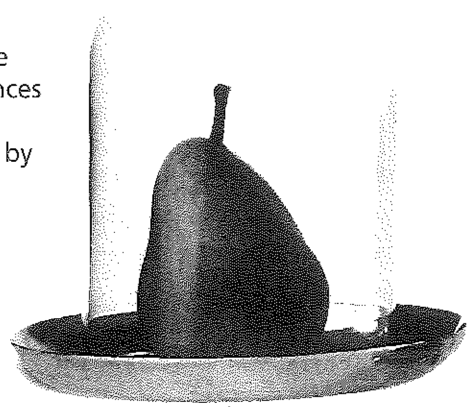
FIGURE 10

Open and Closed Systems

A wood fire is an open system because gases escape into the air. A pear in a glass dome is a closed system because the reactants and products are contained inside the dome.
Problem Solving *What masses would you need to measure before and after a wood fire to show conservation of mass?*

Open System
Except for the ash, products of the wood fire have escaped up the chimney or into the room.

Closed System
The total mass of the pear and the substances produced during its decay are contained by the glass dome.



Fresh pear

Decayed pear

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Balancing Chemical Equations

The principle of conservation of mass means that the same number of atoms exists in the products as in the reactants. **To describe a reaction accurately, a chemical equation must show the same number of each type of atom on both sides of the equation.** Chemists say an equation is balanced when it accurately represents conservation of mass. How can you write a balanced chemical equation?

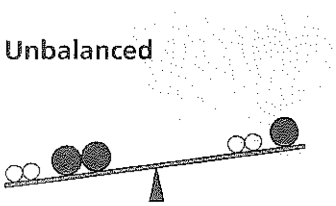
❶ Write the Equation Suppose you want to write a balanced chemical equation for the reaction between hydrogen and oxygen that forms water. To begin, write the correct formulas for both reactants and product.

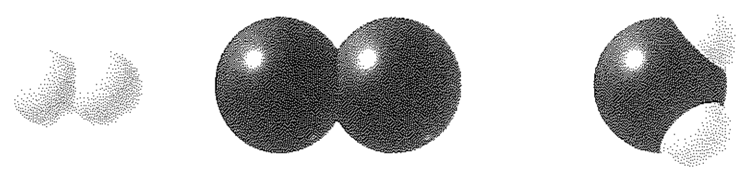
$$H_2 + O_2 \longrightarrow H_2O$$

Reactants | Products

Place the reactants, H_2 and O_2, on the left side of the arrow, separated by a plus sign. Then write the product, H_2O, on the right side of the arrow.

❷ Count the Atoms Count the number of atoms of each element on each side of the equation. You find two atoms of oxygen in the reactants but only one atom of oxygen in the product.



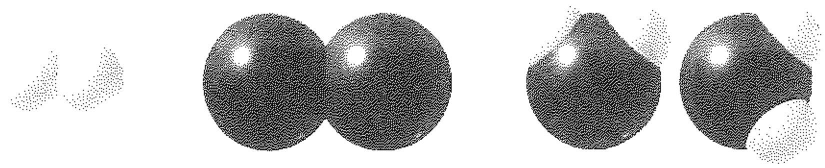


How can you get the number of oxygen atoms on both sides to be the same? You cannot change the formula for water to H_2O_2 because H_2O_2 is the formula for hydrogen peroxide, a completely different compound. So, how can you show that mass is conserved?

❸ Use Coefficients to Balance Atoms To balance the equation, use coefficients. A **coefficient** (koh uh FISH unt) is a number placed in front of a chemical formula in an equation. It tells you how many atoms or molecules of a reactant or a product take part in the reaction. If the coefficient is 1, you don't need to write it.

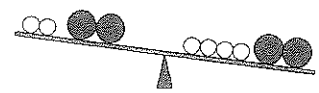
Balance the number of oxygen atoms by writing the coefficient 2 for water. That's like saying "2 × H_2O." Now there are two oxygen atoms—one in each molecule of water.

$$H_2 + O_2 \longrightarrow 2\,H_2O$$



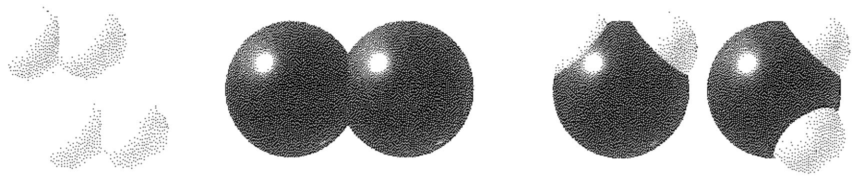
2 hydrogen atoms + 2 oxygen atoms ⟶ 2 oxygen atoms, 4 hydrogen atoms

Unbalanced



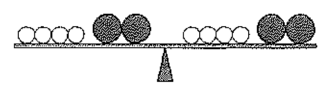
Balancing the oxygen atoms throws off the hydrogen atoms. There are now two hydrogen atoms in the reactants and four in the product. How can you balance the hydrogen? Try doubling the number of hydrogen atoms on the left side of the equation by writing the coefficient 2 for hydrogen.

$$2\,H_2 + O_2 \longrightarrow 2\,H_2O$$



4 hydrogen atoms + 2 oxygen atoms ⟶ 2 oxygen atoms, 4 hydrogen atoms

Balanced



4 Look Back and Check The equation is balanced. It tells you that two molecules of hydrogen react with one molecule of oxygen to yield two molecules of water. Count the atoms in the balanced equation again to see that the equation is correct.

Math Analyzing Data

Balancing Chemical Equations

Magnesium metal (Mg) reacts with oxygen gas (O_2) forming magnesium oxide (MgO). To write a balanced equation for this reaction, first write the equation using the formulas of the reactants and products. Then, count the number of atoms of each element.

1. Balancing Chemical Equations Balance the equation for the reaction of sodium metal (Na) with oxygen gas (O_2), forming sodium oxide (Na_2O).
2. Balancing Chemical Equations Balance the equation for the reaction of tin (Sn) with chlorine gas (Cl_2), forming tin chloride ($SnCl_2$).

Balancing Equations

1. Write the Equation
   $Mg + O_2 \longrightarrow MgO$
2. Count the Atoms
   $Mg + O_2 \longrightarrow MgO$
   1 2 1 1
3. Use Coefficients to Balance the Atoms
   $Mg + O_2 \longrightarrow 2\,MgO$
   2 2
   $2\,Mg + O_2 \longrightarrow 2\,MgO$
   2 2 2 2
4. Look Back and Check

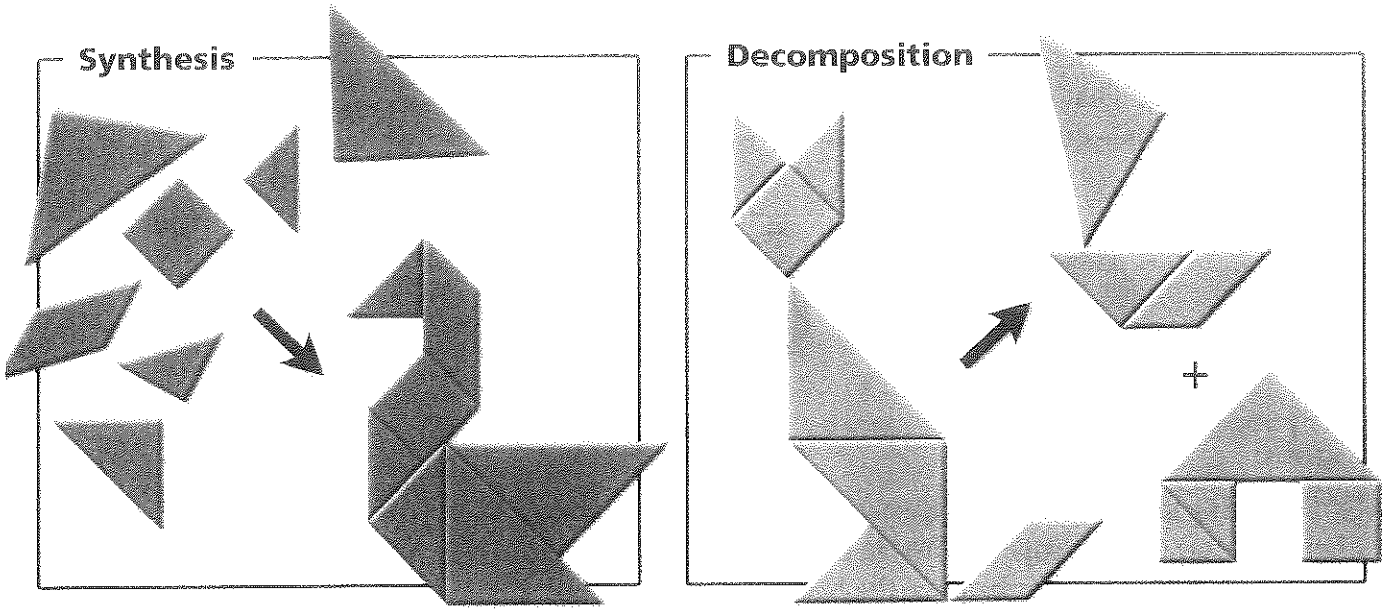


FIGURE 11
Types of Reactions
Three categories of chemical reactions are synthesis, decomposition, and replacement. Making Models *How do these different geometric shapes act as models for elements and compounds in reactions?*

Classifying Chemical Reactions
Substances may combine to make a more complex substance. They may break apart to make simpler substances. Or, they may even exchange parts. In each case, new substances form. **Many chemical reactions can be classified in one of three categories: synthesis, decomposition, or replacement.**

Synthesis Have you ever listened to music from a synthesizer? You can hear many different notes and types of sounds combined to make music. To synthesize is to put things together. In chemistry, when two or more elements or compounds combine to make a more complex substance, the process is called **synthesis** (SIN thuh sis). The reaction of hydrogen and oxygen to make water is a synthesis reaction.

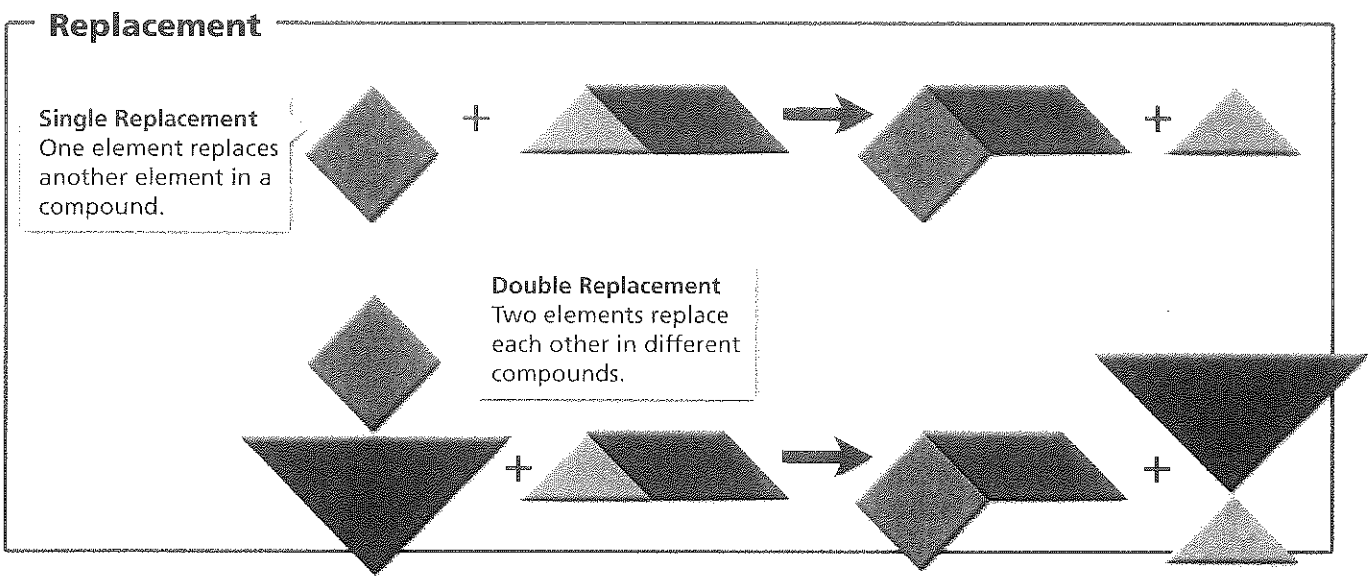
Decomposition In contrast to a synthesis reaction, a process called **decomposition** breaks down compounds into simpler products. You may have a bottle of hydrogen peroxide (H_2O_2) in your house to clean cuts. If you keep such a bottle for a very long time, you'll have water instead. The hydrogen peroxide decomposes into water and oxygen gas.

$$2\,H_2O_2 \longrightarrow 2\,H_2O + O_2$$

Replacement When one element replaces another in a compound, or when two elements in different compounds trade places, the process is called **replacement.** Look at this example:

$$2\,Cu_2O + C \longrightarrow 4\,Cu + CO_2$$

Copper metal can be obtained by heating copper oxide with carbon. The carbon takes the place of copper.



The reaction between copper oxide and carbon is called a *single* replacement reaction because one element, carbon, replaces another element, copper, in the compound. In a *double* replacement reaction, elements in one compound appear to "trade places" with elements in another compound. The following reaction is an example of a double replacement:

$$FeS + 2\,HCl \longrightarrow FeCl_2 + H_2S$$

Use Figure 11 to help you track what happens to elements in different types of chemical reactions.

Section 2 Assessment

Target Reading Skill Building Vocabulary Use your definitions to help you answer the questions.

Reviewing Key Concepts

1. a. Identifying What do the formulas, arrow, and plus signs in a chemical equation tell you?
   b. Comparing and Contrasting How are reactants and products treated the same in a chemical reaction? How are they treated differently?
2. a. Summarizing In your own words, state the meaning of the principle of conservation of mass.
   b. Applying Concepts If the total mass of the products of a reaction is 250 g, what was the total mass of the reactants?
3. a. Reviewing What are three types of chemical reactions?
   b. Inferring What is the smallest possible number of products in a decomposition reaction?
   c. Classifying Classify the following reaction:

$$P_4O_{10} + 6\,H_2O \longrightarrow 4\,H_3PO_4$$

Math Practice

Balance the following equations:

4. $Fe_2O_3 + C \longrightarrow Fe + CO_2$
5. $SO_2 + O_2 \longrightarrow SO_3$

Technology and Society

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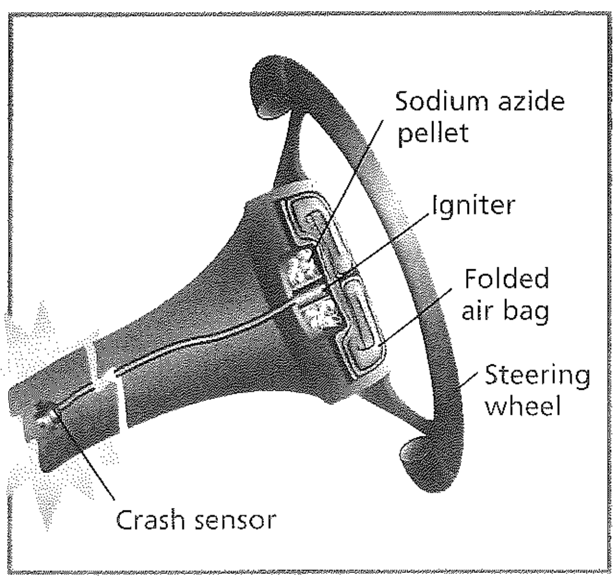
Air Bags

What moves faster than 300 km/h, inflates in less than a second, and saves lives? An air bag, of course! When a moving car is suddenly stopped in a crash, objects inside the car keep moving forward. Death or serious injury can result when passengers hit the hard parts of the car's interior. Air bags, working with seat belts, can slow or stop a person's forward motion in a crash.

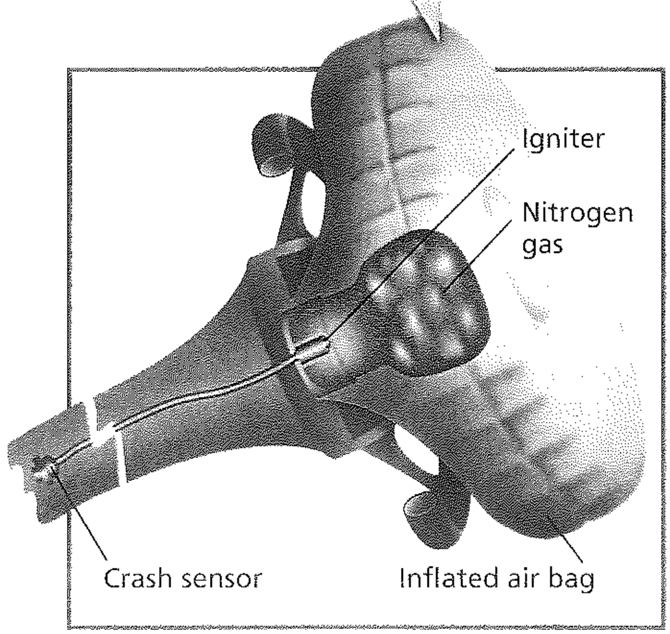
How Do Air Bags Increase Safety?

Before front air bags became a requirement in the 1990s, seat belts were the only restraints for passengers in cars. Seat belts do a great job of keeping people from flying forward in a crash, but even with seat belts, some movement takes place. Air bags were designed as a second form of protection. They provide a buffer zone between a person and the steering wheel, dashboard, or windshield.

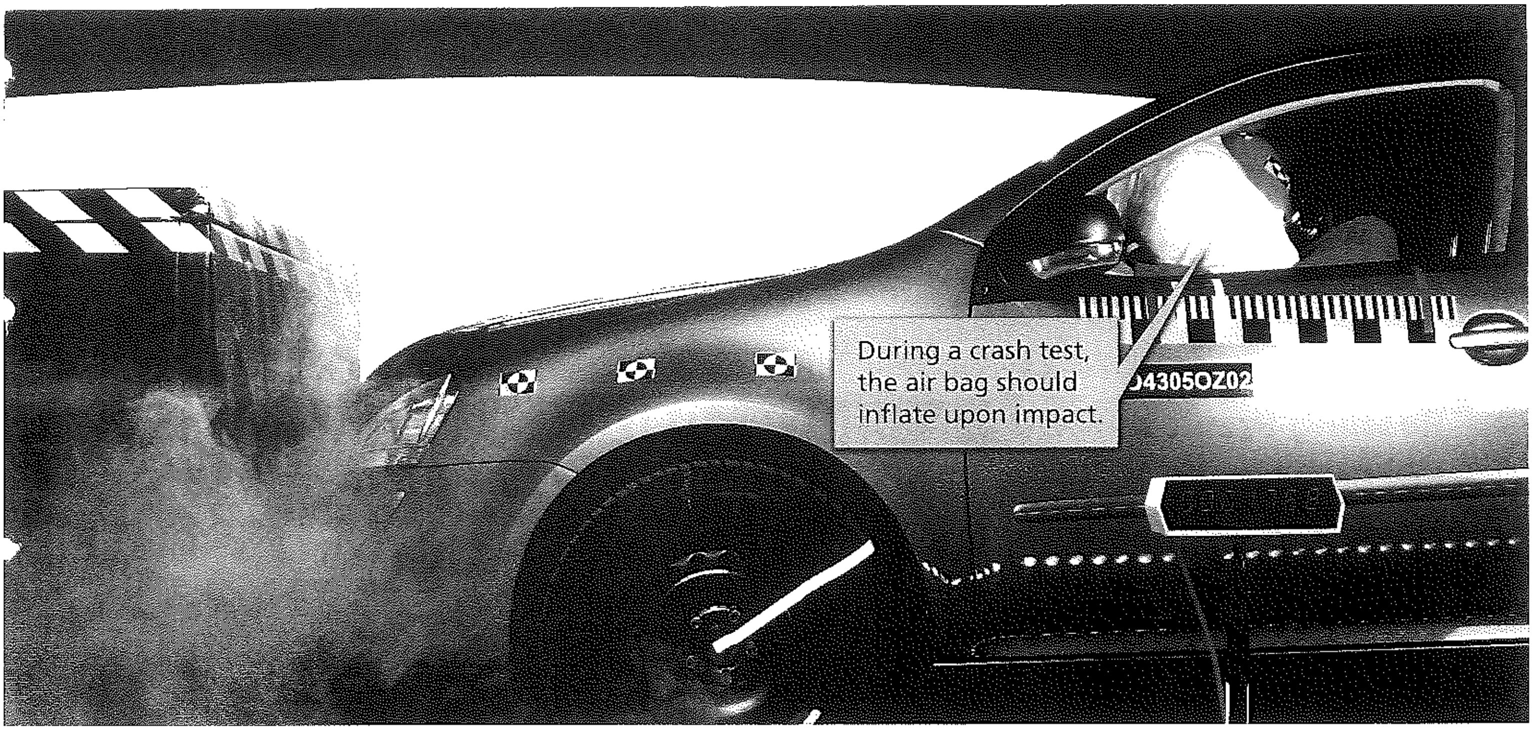


Collision Detected
The crash sensor is located toward the front of the car. The sensor detects an impact and sends a signal to the air bag igniter to start the chemical reaction.

$$2\,NaN_3 \longrightarrow 2\,Na + 3\,N_2$$

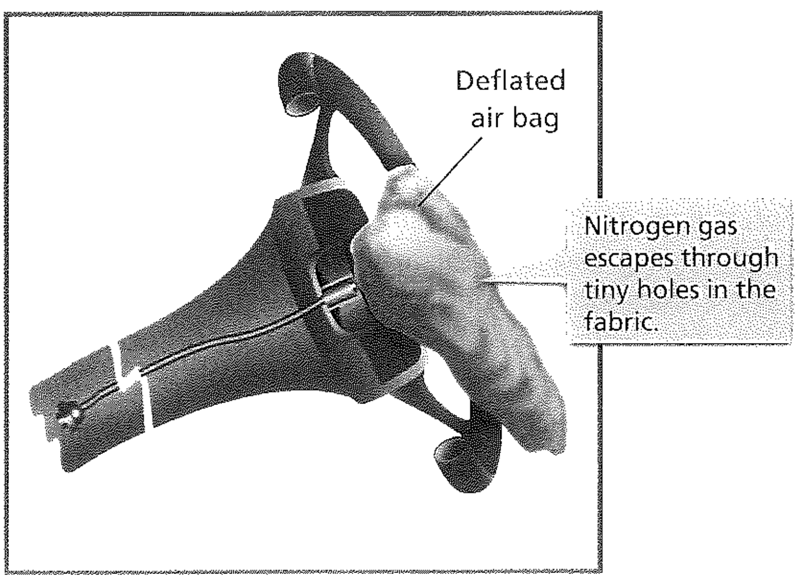


Air Bag Inflates
Pellets of a compound called sodium azide (NaN_3) are heated, causing a rapid decomposition reaction. This reaction releases sodium metal (Na) and nitrogen gas (N_2), which inflate the air bag in about 30 milliseconds.



Cushion or Curse?

Air bags save hundreds of lives each year. Still, if your body is too close to the air bag when it inflates, the impact of the expanding bag may do more harm than good. Front air bags are designed for adults but can pose a danger to smaller, lightweight adults and children. The risk of death to children who ride in the front seat is about one-third higher than the risk if they ride in back. That is why children should never ride in a front seat. They are safer in the back seat.



Air Bag Deflates
Tiny holes in the fabric of the air bag allow some of the nitrogen gas to escape, so the bag starts to deflate by the time a person makes contact with it. In this way, the air bag provides a deflating cushion that slows forward movement.

▲ Car manufacturers must test their vehicles to verify that they meet minimum government safety standards. New cars are required to have air bags on both the driver and passenger sides.

Weigh the Impact

1. Identify the Need
Air bags are called supplemental restraint systems. Why is it so important to restrain people in a collision?

2. Research
Use the Internet to learn how air bags are being changed, added, and redesigned to improve their safety and effectiveness.

3. Write
Choose one type of new air bag technology and summarize it in a few short paragraphs.

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Section 3

Controlling Chemical Reactions

Reading Preview

Key Concepts

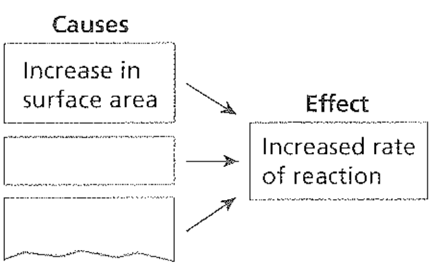
- How is activation energy related to chemical reactions?
- What factors affect the rate of a chemical reaction?

Key Terms

- activation energy
- concentration
- catalyst
- enzyme
- inhibitor

Target Reading Skill

Relating Cause and Effect As you read, identify the factors that can cause the rate of a chemical reaction to increase. Write the information in a graphic organizer like the one below.



Lab zone Discover Activity

Can You Speed Up or Slow Down a Reaction?

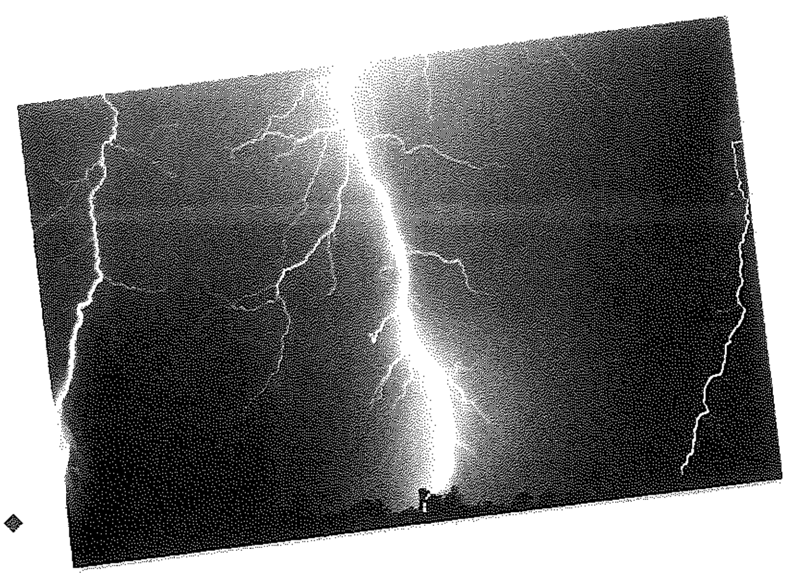
1. Put on your safety goggles and lab apron.
2. Obtain three 125-mL solutions of vitamin C and water—one at room temperature, one at about 75°C, and one chilled to between 5°C and 10°C.
3. Add 3 drops of iodine solution to each container and stir each with a clean spoon. Compare changes you observe in the solutions.
4. Clean up your work area and wash your hands.

Think It Over

Inferring What conclusion can you make about the effect of temperature on the reaction of iodine and vitamin C?

With a splintering crash, a bolt of lightning strikes a tree in the forest. The lightning splits the tree and sets fire to the leaves on the ground below it. The leaves are dry and crisp from drought. The crackling fire burns a black patch in the leaves. The flames leap to nearby dry twigs and branches on the ground. Soon, the forest underbrush is blazing, and the barks of trees start burning. Miles away in an observation tower, a ranger spots the fire and calls in the alarm—"Forest fire!"

Forest fires don't just happen. Many factors contribute to them—lightning and drought to name just two. But, in general, wood does not always burn easily. Yet, once wood does begin to burn, it gives off a steady supply of heat and light. Why is it so hard to start and maintain some chemical reactions?



◀ **Lightning can supply enough energy to ignite a forest fire.**

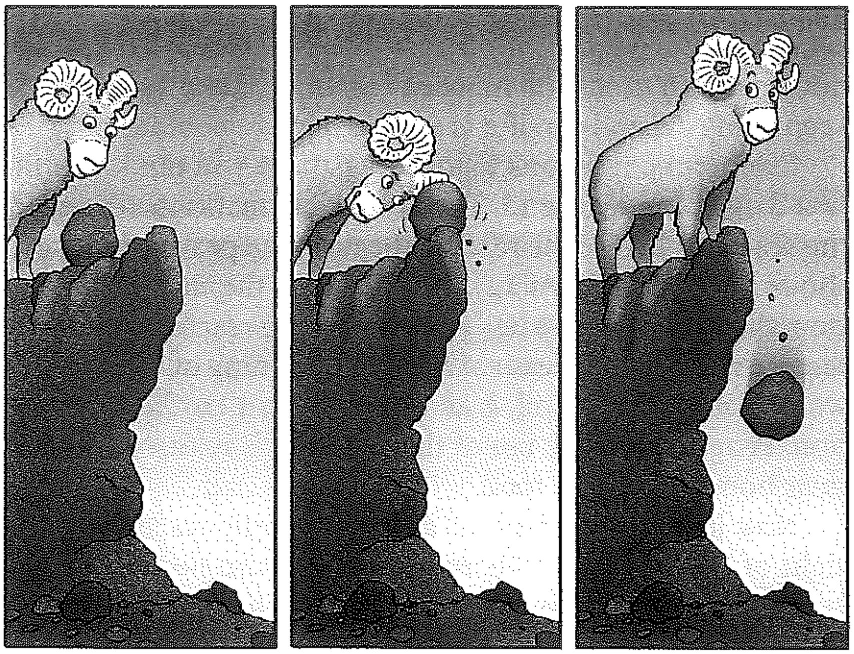


FIGURE 12
Modeling Activation Energy
The rock at the top of this hill cannot roll down the hill until a small push gets it going.
Making Models *How is this cartoon a kind of model for the role of activation energy in a chemical reaction?*

Energy and Reactions

To understand why it can be hard to start some chemical reactions, look at Figure 12. The rock at the top of the hill can fall over the cliff, releasing energy when it crashes into the rocks at the bottom. Yet it remains motionless until it's pushed over the small hump.

Activation Energy Every chemical reaction is like that rock. A reaction won't begin until the reactants have enough energy to push them "over the hump." The energy is used to break the chemical bonds of the reactants. Then, the atoms begin to form the new chemical bonds of the products. The **activation energy** is the minimum amount of energy needed to start a chemical reaction. **All chemical reactions need a certain amount of activation energy to get started.**

Consider the reaction in which hydrogen and oxygen form water. This reaction gives off a large amount of energy. But if you just mix the two gases together, they can remain unchanged for years. For the reaction to start, a tiny amount of activation energy is needed—even just an electric spark. Once a few molecules of hydrogen and oxygen react, the rest will quickly follow because the first few reactions provide activation energy for more molecules to react. Overall, the reaction releases more energy than it uses. Recall from Section 1 that this type of reaction is described as exothermic.

Reading Checkpoint **What is the function of a spark in a reaction between hydrogen gas and oxygen gas?**

Exothermic and Endothermic Reactions Every chemical reaction needs activation energy to get started. Whether or not a reaction needs still more energy from the environment to keep going depends on if it is exothermic or endothermic.

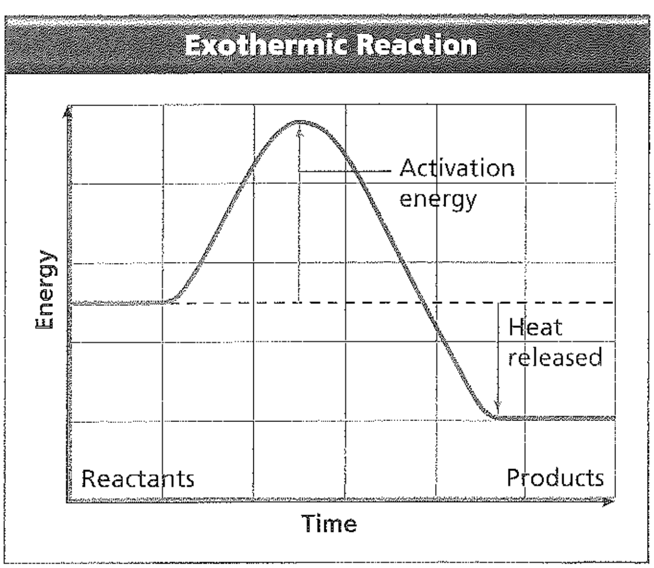
Exothermic reactions follow the pattern you can see in the first diagram in Figure 13. The dotted line marks the energy of the reactants before the reaction begins. The peak in the graph shows the activation energy. Notice that at the end of the reaction, the products have less energy than the reactants. This difference results in a release of heat. The burning of fuel, such as wood, natural gas, or oil, is an example of an exothermic reaction. People can make use of the heat that is released to warm their homes and cook food.

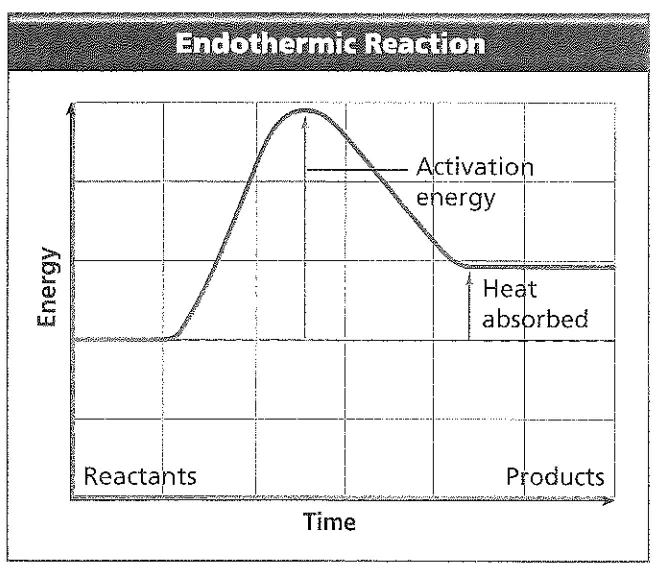
Now look at the graph of an endothermic reaction on the right of Figure 13. Endothermic reactions also need activation energy to get started. But, in addition, they need energy to keep going. Notice that the energy of the products is higher than that of the reactants. This difference tells you that the reaction must absorb energy to continue.

When you placed baking soda in vinegar in the Discover activity in Section 1, the thermal energy already present in the solution was enough to start the reaction. The reaction continued by drawing energy from the solution, making the solution feel colder. But most endothermic reactions require a continuous source of heat to occur. For example, baking bread requires added heat until the baking process is completed.

Reading Checkpoint **In what type of reaction do the reactants have less energy than the products?**

FIGURE 13
Energy Changes in Chemical Reactions
Both exothermic and endothermic reactions need energy to get started. Reading Graphs *What does the peak in the curve in each graph represent?*





Rates of Chemical Reactions

Chemical reactions don't all occur at the same rate. Some, like explosions, are very fast. Others, like the rusting of metal, are much slower. Also, a particular reaction can occur at different rates depending on the conditions.

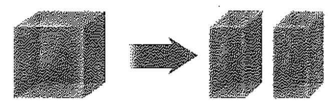
If you want to make a chemical reaction happen faster, you need to get more reactant particles together more often and with more energy. To slow down a reaction, you need to do the opposite. **Chemists can control rates of reactions by changing factors such as surface area, temperature, and concentration, and by using substances called catalysts and inhibitors.**

Surface Area Look at Figure 14. The wreckage used to be a grain elevator. It exploded when grain dust ignited in the air above the stored grain. Although the grain itself doesn't react violently in air, the grain dust can. This difference is related to surface area. When a chunk of solid substance reacts with a liquid or gas, only the particles on the surface of the solid come into contact with the other reactant. But if you break the solid into smaller pieces, more particles are exposed and the reaction happens faster. Sometimes, speeding up a reaction this way is dangerous. Other times, increasing surface area can be useful. For example, chewing your food breaks it into smaller pieces that your body can digest more easily and quickly.

Lab zone Skills Activity

Interpreting Data

1. Measure the length and width of a face of a gelatin cube.
2. Calculate the area of that face of the cube.
   Area = length × width
3. Repeat for each of the other five faces. Then add the six values to get the total surface area.
4. Using a plastic knife, cut the cube in half. Add the surface areas of the two pieces to get a new total.



5. How did the original total surface area compare with the total area after the cube was cut?
6. Predict the total surface area if you cut each cube in two again. If you have time, test your prediction.

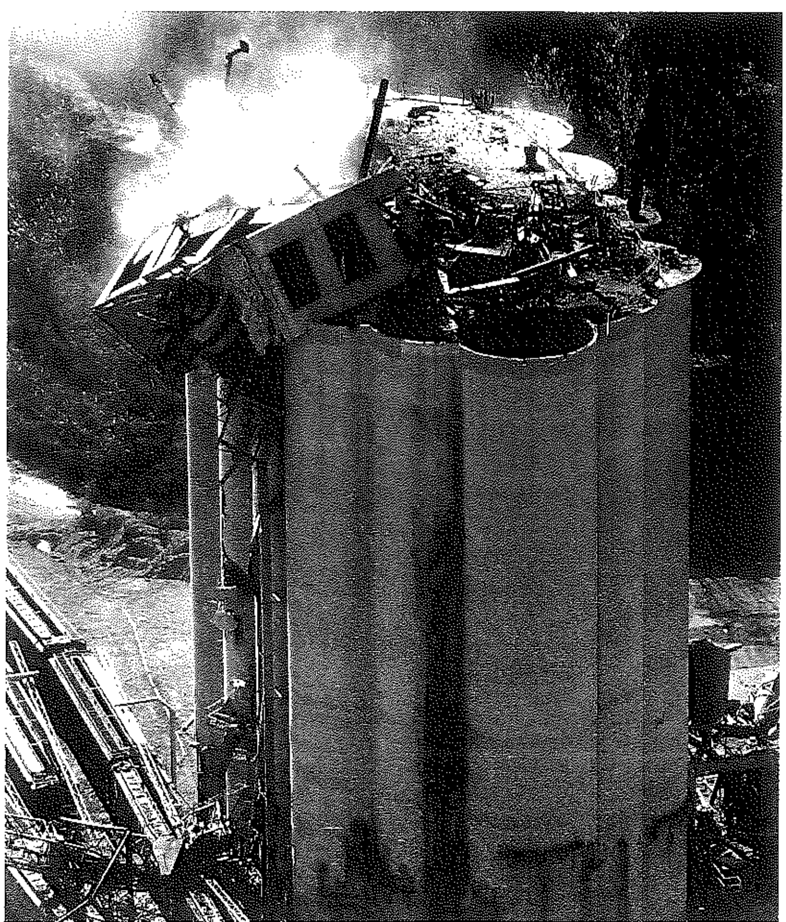


FIGURE 14
Surface Area and Reaction Rate
Grain dust reacts explosively with oxygen. Minimizing grain dust in a grain elevator can help prevent an accident like the one shown here.

Temperature Another way to increase the rate of a reaction is to increase its temperature. When you heat a substance, its particles move faster. Faster-moving particles increase the reaction rate in two ways. First, the particles come in contact more often, which means there are more chances for a reaction to happen. Second, faster-moving particles have more energy. This increased energy causes more particles of the reactants to get over the activation energy "hump."

In contrast, reducing temperature slows down reaction rates. For example, milk contains bacteria, which carry out thousands of chemical reactions as they live and reproduce. At room temperature, those reactions happen faster and milk spoils more quickly. You store milk and other foods in the refrigerator because keeping foods cold slows down those reactions, so your foods stay fresh longer.

Concentration A third way to increase the rate of a chemical reaction is to increase the concentration of the reactants. **Concentration** is the amount of a substance in a given volume. For example, adding a small spoonful of sugar to a glass of lemonade will make it sweet. But adding a large spoonful of sugar makes the lemonade sweeter. The glass with more sugar has a greater concentration of sugar molecules.

Increasing the concentration of reactants supplies more particles to react. Compare the two reactions of acid and magnesium metal in Figure 15. The test tube on the left has a lower concentration of acid. This reaction is slower than the one on the right, where the acid concentration is higher. You see evidence for the increased rate of reaction in the greater amount of gas bubbles produced.

Reading Checkpoint **Why may an increase in temperature affect the rate of a chemical reaction?**

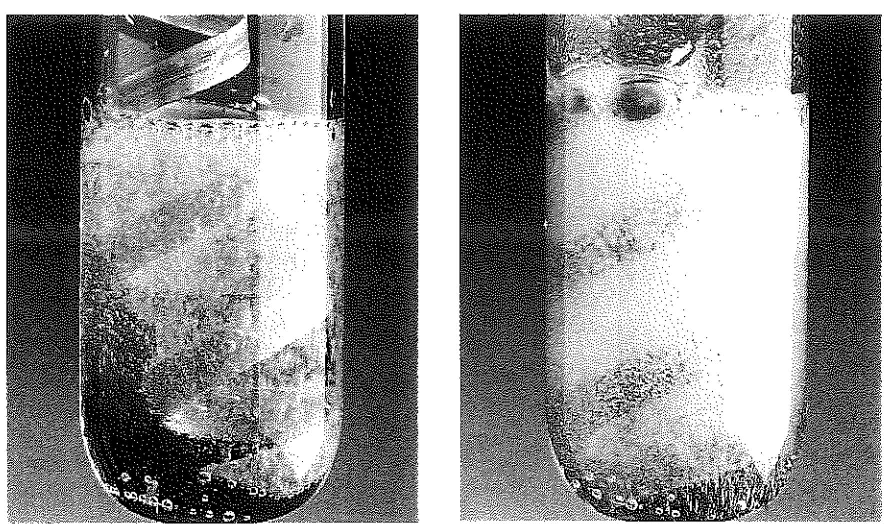


FIGURE 15
Concentration and Reaction Rate
Bubbles of hydrogren gas form when magnesium reacts with acid.
Relating Cause and Effect *What makes the reaction faster in the test tube on the right?*

Catalysts Another way to control the rate of a reaction is to change the activation energy needed. A **catalyst** (KAT uh list) is a material that increases the rate of a reaction by lowering the activation energy. Although catalysts affect a reaction's rate, they are not permanently changed by a reaction. For this reason catalysts are not considered reactants.

Many chemical reactions happen at temperatures that would kill living things. Yet, some of these reactions are necessary for life. The cells in your body (as in all living things) contain biological catalysts called **enzymes** (EN zymz). Your body has thousands of different enzymes. Each one is specific—it affects only one chemical reaction.

As shown in Figure 16, enzymes provide a surface on which reactions can take place. By bringing reactant molecules close together, the enzyme lowers the activation energy needed. In this way, enzymes make chemical reactions that are necessary for life happen at a low temperature.

Inhibitors Sometimes a reaction is more useful when it can be slowed down rather than speeded up. A material used to decrease the rate of a reaction is an **inhibitor.** Most inhibitors work by preventing reactants from coming together. Usually they combine with one of the reactants either permanently or temporarily. Inhibitors include preservatives added to food products to prevent them from becoming stale or spoiling.

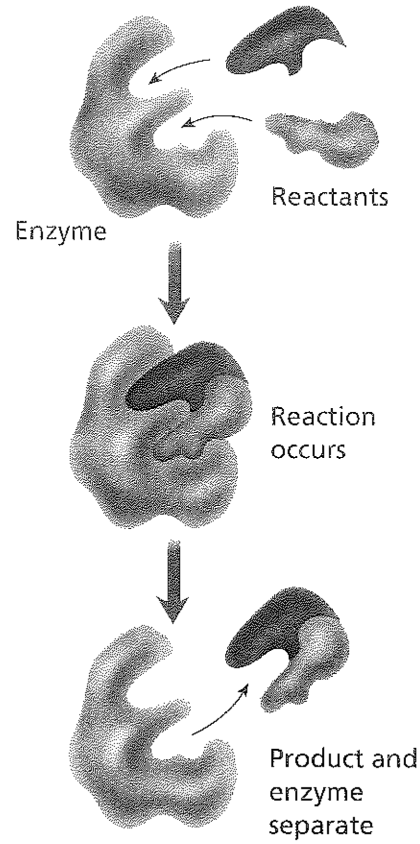


FIGURE 16
Enzyme Action
After a reaction, an enzyme molecule is unchanged.

Section 3 Assessment

Target Reading Skill Relating Cause and Effect Use the information in your graphic organizer about speeding up chemical reactions to help you answer Question 2 below.

Reviewing Key Concepts

1. a. Defining What is activation energy?
   b. Describing What role does activation energy play in chemical reactions?
   c. Making Generalizations Look at the diagram in Figure 13, and make a generalization about activation energy in exothermic and endothermic reactions.
2. a. Identifying What are four ways that chemists can control the rates of chemical reactions?
   b. Applying Concepts Which would react more quickly in a chemical reaction: a single sugar cube or an equal mass of sugar crystals? Explain.

Lab zone At-Home Activity

Comparing Reaction Rates Place an iron nail in a plastic cup. Add enough water to almost cover the nail. Place a small piece of fine steel wool in another cup and add the same amount of water. Ask family members to predict what will happen overnight. The next day, examine the nail and steel wool. Compare the amount of rust on each. Were your family's predictions correct? Explain how surface areas affect reaction rates.

Lab zone **Skills Lab**

Temperature and Enzyme Activity

Problem

Catalase is an enzyme that speeds up the breakdown of hydrogen peroxide into water and oxygen gas. Hydrogen peroxide is a poisonous waste product of reactions in living things. How does temperature affect the action of the enzyme catalase?

Skills Focus

calculating, interpreting data, drawing conclusions

Materials

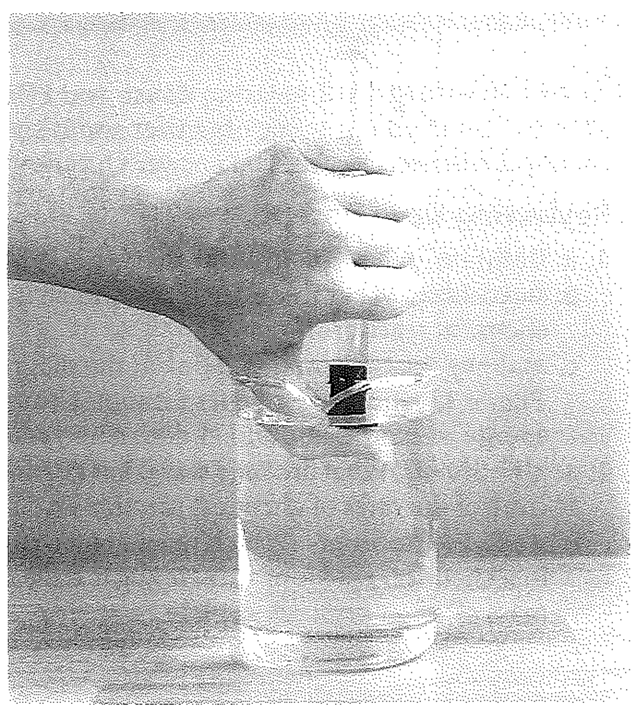
- forceps
- stopwatch
- test tube with a one-hole stopper
- 0.1% hydrogen peroxide solution
- filter paper disks soaked in liver preparation (catalase enzyme) and kept at four different temperatures (room temperature, 0–4°C, 37°C, and 100°C)
- container to hold water (beaker or bowl)

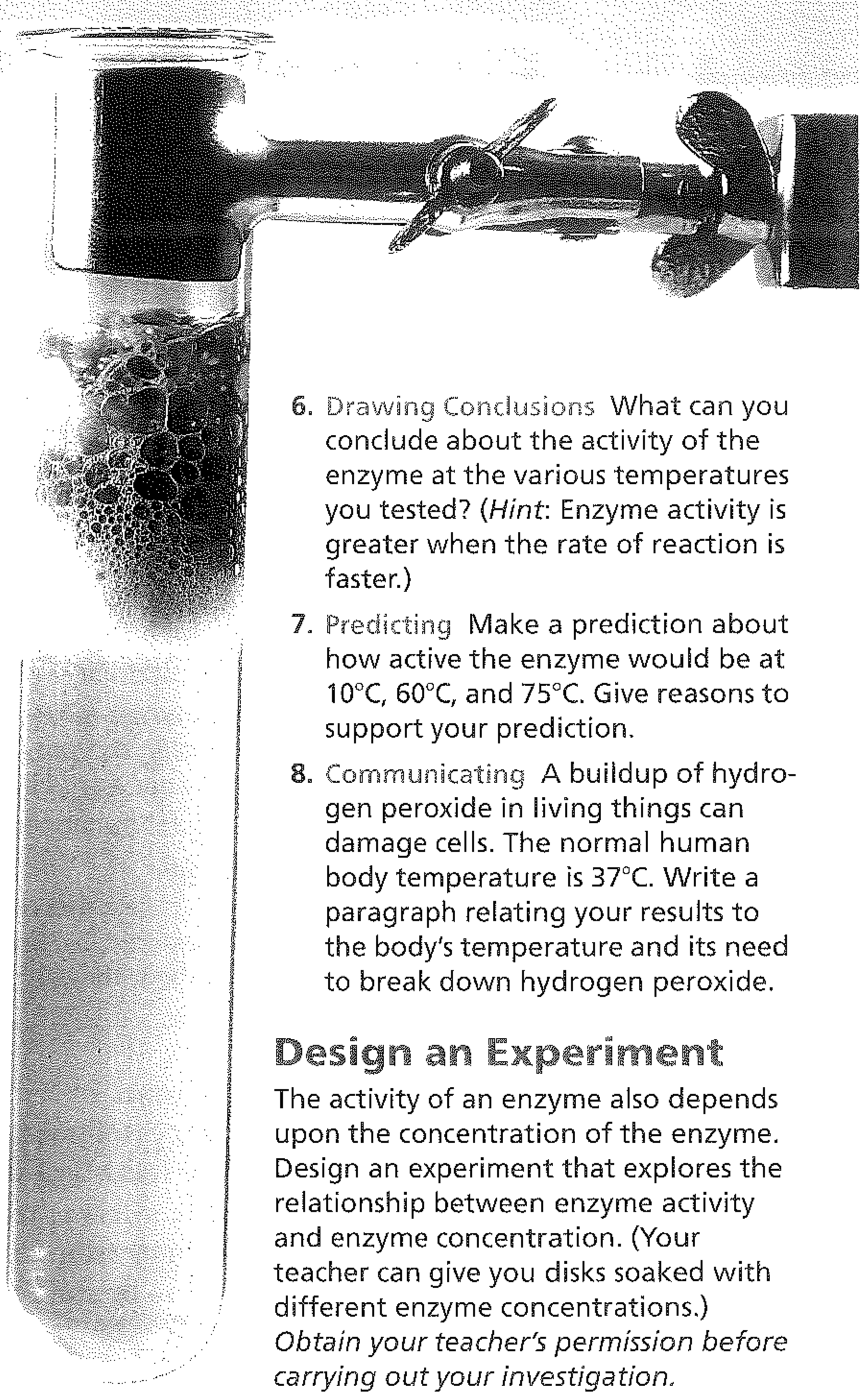
Procedure

1. Form a hypothesis that predicts how the action of the catalase enzyme will differ at the different temperatures to be tested.
2. Fill a container with water. Then fill a test tube with 0.1% hydrogen peroxide solution until the test tube is overflowing. Do this over a sink or the container of water.
3. Make a data table similar to the one shown.
4. Moisten the small end of a one-hole stopper with water.
5. Using forceps, remove a filter paper disk soaked in liver preparation (catalase enzyme) that has been kept at room temperature. Stick it to the moistened end of the one-hole stopper.
6. Your partner should be ready with the stopwatch for the next step.
7. Place the stopper firmly into the test tube, hold your thumb over the hole, and quickly invert the test tube. Start the stopwatch. Put the inverted end of the test tube into the container of water, as shown in the photograph, and remove your thumb.

Data Table

Temperature (°C)	Time (sec)	Average Time for Class (sec)





Catalase from blood reacts with hydrogen peroxide.

8. Observe what happens to the filter paper inside the test tube. Record the time it takes for the disk to rise to the top. If the disk does not rise within 2 minutes, record "no reaction" and go on to Step 9.
9. Rinse the test tube and repeat the procedure with catalase enzyme disks kept at 0°C, 37°C, and 100°C. **CAUTION:** *When you remove the disk kept in the hot water bath, do not use your bare hands. Avoid spilling the hot water.*

Analyze and Conclude

1. Observing What makes the disk float to the top of the inverted test tube?
2. Calculating Calculate the average time for each temperature based on the results of the entire class. Enter the results in your data table.
3. Graphing Make a line graph of the data you collected. Label the horizontal axis (*x*-axis) "Temperature" with a scale from 0°C to 100°C. Label the vertical axis (*y*-axis) "Time" with a scale from 0 to 30 seconds. Plot the class average time for each temperature.
4. Interpreting Data What evidence do you have that your hypothesis from Step 1 is either supported or not supported?
5. Interpreting Data How is the time it takes the disk to rise to the top of the inverted tube related to the rate of the reaction?
6. Drawing Conclusions What can you conclude about the activity of the enzyme at the various temperatures you tested? (*Hint*: Enzyme activity is greater when the rate of reaction is faster.)
7. Predicting Make a prediction about how active the enzyme would be at 10°C, 60°C, and 75°C. Give reasons to support your prediction.
8. Communicating A buildup of hydrogen peroxide in living things can damage cells. The normal human body temperature is 37°C. Write a paragraph relating your results to the body's temperature and its need to break down hydrogen peroxide.

Design an Experiment

The activity of an enzyme also depends upon the concentration of the enzyme. Design an experiment that explores the relationship between enzyme activity and enzyme concentration. (Your teacher can give you disks soaked with different enzyme concentrations.) *Obtain your teacher's permission before carrying out your investigation.*

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Section 4

Integrating Health

Fire and Fire Safety

Reading Preview

Key Concepts

- What are the three things necessary to maintain a fire?
- Why should you know about the causes of fire and how to prevent a fire?

Key Terms

- combustion
- fuel

Target Reading Skill

Using Prior Knowledge Before you read, write what you know about fire safety in a graphic organizer like the one below. As you read, continue to write in what you learn.

What You Know
1. A fire needs fuel to burn. 2.

What You Learned
1. 2.

Firefighters battle a blaze. ▼

Lab zone Discover Activity

How Does Baking Soda Affect a Fire?

1. Put on your safety goggles.
2. Secure a small candle in a holder or a ball of clay. After instructions from your teacher, use a match to light the candle.
3. Place a beaker next to the candle. Measure 1 large spoonful of baking soda into the beaker. Add about 100 mL of water and stir. Add about 100 mL of vinegar.
4. As soon as the mixture stops foaming, tip the beaker as if you are pouring something out of it onto the flame. **CAUTION:** *Do not pour any liquid on the candle.*
5. Observe what happens to the flame.

Think It Over

Developing Hypotheses The gas produced in the beaker was carbon dioxide, CO_2. Based on the results of this experiment, develop a hypothesis to explain what you observed in Step 5.

The call comes in. Fire! A blaze has been spotted in a warehouse near gasoline storage tanks. Firefighters scramble aboard the ladder truck and the hose truck. Lights flash, sirens blare, and traffic swerves to clear a path for the trucks. The firefighters know from their training that fire is a chemical reaction that can be controlled—but only if they reach it in time.

Understanding Fire

Fire is the result of **combustion,** a rapid reaction between oxygen and a substance called a fuel. A **fuel** is a material that releases energy when it burns. Common fuels include oil, wood, gasoline, natural gas, and paper. Combustion of these types of fuel always produces carbon dioxide and water. When fuels don't burn completely, products such as smoke and poisonous gases may be produced.

The Fire Triangle Although a combustion reaction is very exothermic and fast, a fire cannot start unless conditions are right. **The following three things are necessary to start and maintain a fire—fuel, oxygen, and heat.**

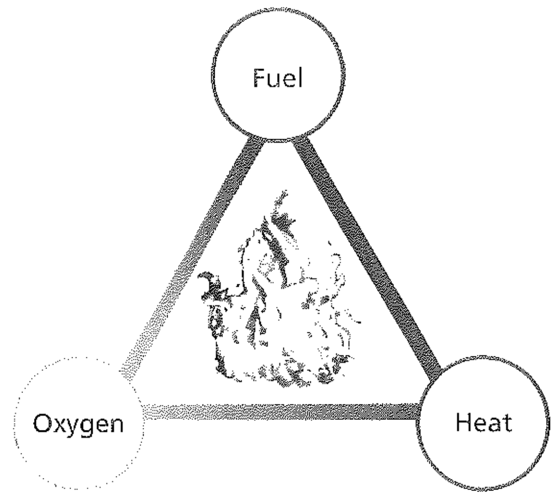
You probably know that oxygen is one of the gases in air. About 20 percent of the air around you is composed of oxygen gas. If air can reach the fuel, so can oxygen. A large fire can create a strong draft that pulls air toward it. As the air around the flame is heated, it rises rapidly. Cooler air flows toward the fire, replacing the heated air and bringing a fresh supply of oxygen. If you stand in front of a fire in a fireplace, you can feel the air flow toward the fire.

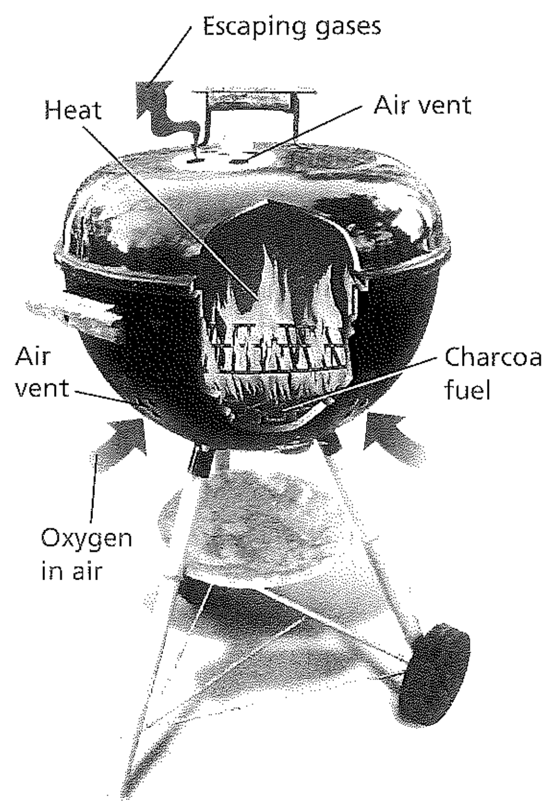
Heat is a part of the fire triangle. Fuel and oxygen can be together, but they won't react until something provides the activation energy to start combustion. This energy can come from a lighted match, an electric spark, or the heat from a stove. Once combustion starts, the heat released supplies more activation energy to keep the reaction going.

Once started, a fire can continue burning as long as all components of the fire triangle are available. Coal in abandoned mines under the town of Centralia, Pennsylvania, started burning in 1962. The coal is still burning. Many old airshafts lead into the tunnels. Because some airshafts cannot be located and sealed, air continues to flow into the mines, supporting the fire. Heat and poisonous gases coming up from the fire through cracks in the ground made living in Centralia difficult. Everyone eventually moved away. No one knows how long this fire will continue to burn.

Reading Checkpoint **What is heat's role in starting a fire?**

FIGURE 17
The Fire Triangle
The fire triangle can be controlled in the grill below. If any point of the fire triangle is missing, a fire will not continue.
Applying Concepts *How would closing the lower air vents affect the fire?*





Go Online
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For: Links on fire safety
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Controlling Fire Use your knowledge of chemical reactions to think of ways to control a fire. What if you remove one part of the fire triangle? For example, you can get the fuel away from the flames. You can also keep oxygen from getting to the fuel. Finally, you can cool the combustion reaction.

How do firefighters usually fight fires? They use hoses to spray huge amounts of water on the flames. Water removes two parts of the fire triangle. First, water covers the fuel, which keeps it from coming into contact with oxygen. Second, evaporation of the water uses a large amount of heat, causing the fire to cool. Without heat, there isn't enough energy to continue the combustion. Therefore, the reaction stops.

Home Fire Safety

Every year, fire claims thousands of lives in the United States. **If you know how to prevent fires in your home and what to do if a fire starts, you are better prepared to take action.** You may save your home or even your life! The most common sources of home fires are small heaters, cooking, and faulty electrical wiring. The fires that cause the most deaths start from carelessness with cigarettes.

Fighting Fires You can fight a small fire by using what you know about the fire triangle. For example, carbon dioxide gas can smother a fire by preventing contact between the fuel and oxygen in the air. Therefore, you can put out a small fire on the stove by throwing baking soda on it. Baking soda decomposes when heated and releases carbon dioxide gas. Or, you can use the cover of a saucepan to cut off the flow of oxygen.

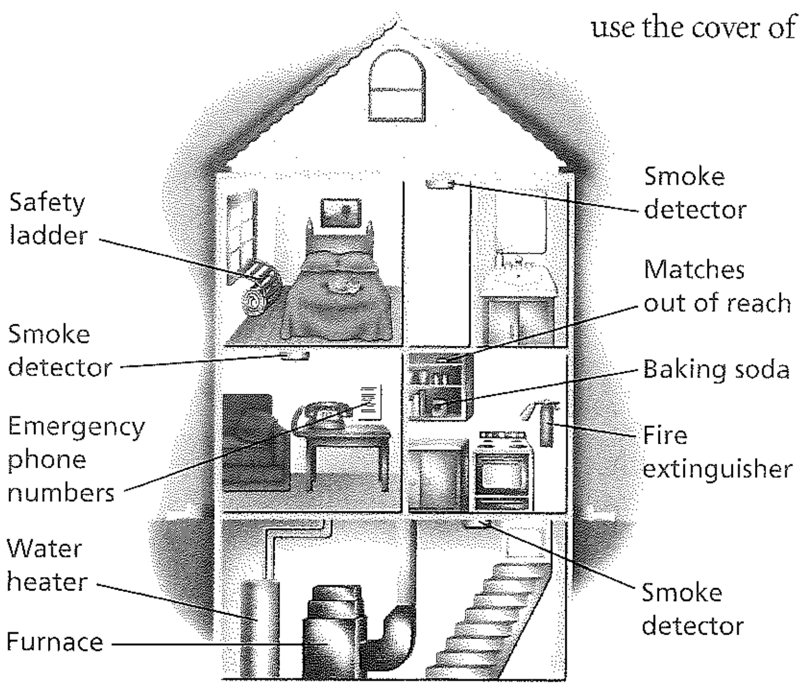


FIGURE 18
A Fire-Safe House
This fire-safe house has many fire-prevention and fire safety features. Inferring *Why are smoke detectors located on every floor?*

A small fire is easy to control. You can cool a match enough to stop combustion just by blowing on it. A small fire in a trash can may be doused with a pan of water. If the fire spreads to the curtains, however, even a garden hose might not deliver enough water to put it out.

One of the most effective ways to fight a small fire is with a fire extinguisher. But a fire that is growing as you fight it is out of control. If a fire is out of control, there is only one safe thing to do—get away from the fire and call the fire department.

Preventing Trouble The best form of fire safety is prevention. Figure 18 shows some features of a fire-safe house. You can also check your home to be sure that all flammable items are stored safely away from sources of flames, such as the kitchen stove. Fires can be dangerous and deadly, but many fires can be prevented if you are careful. Understanding the chemistry of fire gives you a way to reduce risk and increase your family's safety.

Reading Checkpoint **How does baking soda put a fire out?**

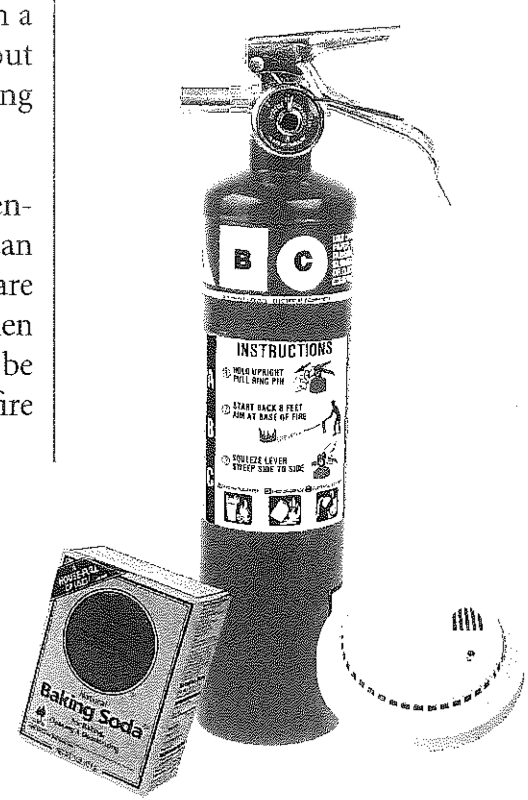


FIGURE 19
Fire-Prevention Devices
Fire extinguishers and baking soda can be used to interrupt the fire triangle. Smoke detectors can help you identify a fire and escape to safety.

Section 4 Assessment

Target Reading Skill Previewing Visuals Review your graphic organizer and revise it based on what you just learned in the section.

Reviewing Key Concepts

1. a. Listing What three things are required for combustion?
   b. Explaining How does the fire triangle help you control fire?
   c. Applying Concepts To stop a forest fire, firefighters may remove all the trees in a strip of land that lies in the path of the fire. What part of the fire triangle is affected? Explain.
2. a. Reviewing Why is it important to know about the causes of fire and how to prevent fires?
   b. Identifying What are the three most common causes of home fires?
   c. Problem Solving Choose one common cause of home fires. Describe measures that can be taken to prevent fires of this type.

Lab zone At-Home Activity

Family Safety Plan Work with your family to formulate a fire safety plan. How can fires be prevented in your home? How can fires be put out if they occur? Is there a functioning smoke detector on each floor of the home, especially near the bedrooms? How can the fire department be contacted in an emergency? Design a fire escape route. Make sure all family members know the route as well as a meeting place outside.

Chapter 6 Study Guide

The BIG Idea **Chemical Changes in Matter** Chemical reactions are processes in which substances react and form one or more new substances.

1 Observing Chemical Change

Key Concepts

- Matter can be described in terms of two kinds of properties—physical properties and chemical properties. Changes in matter can be described in terms of physical changes and chemical changes.
- Chemical changes occur when bonds break and new bonds form.
- Chemical reactions involve two main kinds of changes that you can observe—formation of new substances and changes in energy.

Key Terms

matter
chemistry
physical property
chemical property
physical change
chemical reaction
precipitate
endothermic reaction
exothermic reaction

2 Describing Chemical Reactions

Key Concepts

- Chemical equations use chemical formulas and other symbols instead of words to summarize a reaction.
- The principle of conservation of mass states that, in a chemical reaction, the total mass of the reactants must equal the total mass of the products.
- To describe a reaction accurately, a chemical equation must show the same number of each type of atom on both sides of the equation.
- Many chemical reactions can be classified in one of three categories: synthesis, decomposition, or replacement.

Key Terms

chemical equation
reactant
product
conservation of mass
open system
closed system
coefficient
synthesis
decomposition
replacement

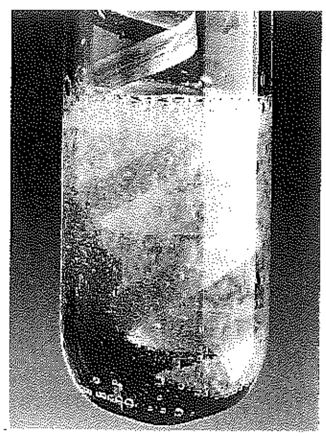
3 Controlling Chemical Reactions

Key Concepts

- All chemical reactions need a certain amount of activation energy to get started.
- Chemists can control rates of reactions by changing factors such as surface area, temperature, and concentration, and by using substances called catalysts and inhibitors.

Key Terms

activation energy
concentration
catalyst
enzyme
inhibitor



4 Fire and Fire Safety

Key Concepts

- The following three things are necessary to start and maintain a fire—fuel, oxygen, and heat.
- If you know how to prevent fires in your home and what to do if a fire starts, you are better prepared to take action.

Key Terms

combustion
fuel

Review and Assessment

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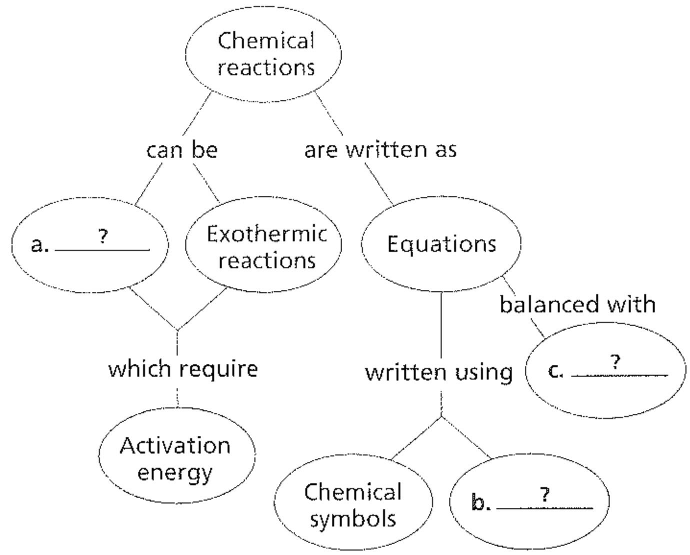
Organizing Information

Concept Mapping Copy the chemical reactions concept map onto a separate sheet of paper. Then complete it and add a title. (For more on Concept Mapping, see the Skills Handbook.)



Reviewing Key Terms

Choose the letter of the best answer.

1. Which of the following is *not* a physical property?
   a. flexibility
   b. ability to catch fire
   c. melting point
   d. ability to conduct electricity
2. A chemical reaction that gives off heat is likely to be
   a. endothermic.
   b. a precipitate.
   c. a physical change.
   d. exothermic.
3. You can balance a chemical equation by changing the
   a. subscripts.
   b. coefficients.
   c. reactants.
   d. products.
4. A chemical reaction in which two elements combine to form a compound is called a
   a. synthesis reaction.
   b. replacement reaction.
   c. decomposition reaction.
   d. precipitation reaction.
5. The activation energy of a chemical reaction
   a. is supplied by a catalyst.
   b. is released at the end.
   c. starts the reaction.
   d. changes with time.
6. A chemical reaction in which a fuel combines rapidly with oxygen is a (an)
   a. inhibited reaction.
   b. combustion reaction.
   c. enzyme reaction.
   d. endothermic reaction.

Writing in Science

Explanation You are a writer for a children's book about chemistry. Write a paragraph that young children would understand that explains the concept of "activation energy." Be sure to use examples, such as the burning of wood or gas.

Review and Assessment

Checking Concepts

7. What are the two kinds of changes that occur in matter? Describe how you can tell one from the other.
8. Why can't you balance a chemical equation by changing the subscripts of the reactants or the products?
9. You find the mass of a piece of iron metal, let it rust, and measure the mass again. The mass has increased. Does this violate the principle of conservation of mass? Explain.
10. How do enzymes in your body make chemical reactions occur at safe temperatures?
11. Why does spraying water on a fire help to put the fire out?
12. How are inhibitors useful in controlling chemical reactions?

Thinking Critically

13. **Problem Solving** Steel that is exposed to water and salt rusts quickly. If you were a shipbuilder, how would you protect a new ship? Explain why your solution works.
14. **Classifying** The following are balanced equations for chemical reactions. Classify each of the equations as synthesis, decomposition, or replacement.
    a. $2\,Al + Fe_2O_3 \longrightarrow 2\,Fe + Al_2O_3$
    b. $2\,Ag + S \longrightarrow Ag_2S$
    c. $CaCO_3 \longrightarrow CaO + CO_2$
    d. $2\,NO + O_2 \longrightarrow 2\,NO_2$
15. **Relating Cause and Effect** Firefighters open doors very carefully because sometimes a room will burst violently into flames when the door is opened. Based on your knowledge of the fire triangle, explain why this happens.
16. **Inferring** Some statues are made of materials that can react in acid rain and begin to dissolve. It has been observed that statues with smooth surfaces are dissolved by acid rain much slower than statues with very detailed carvings. Explain this observation.

Math Practice

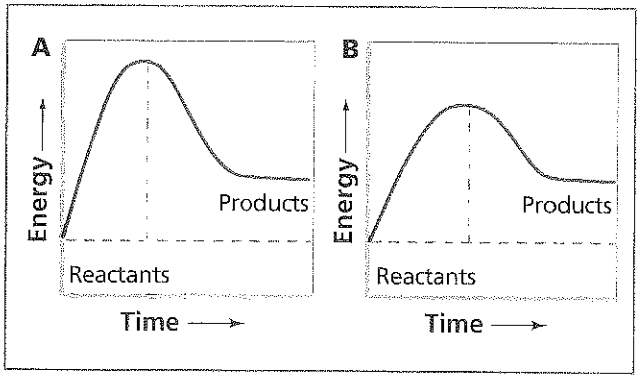
Balance the chemical equations in Questions 17–20.

17. $MgO + HBr \longrightarrow MgBr_2 + H_2O$
18. $N_2 + O_2 \longrightarrow N_2O_5$
19. $C_2H_4 + O_2 \longrightarrow CO_2 + H_2O$
20. $Fe + HCl \longrightarrow FeCl_2 + H_2$

Applying Skills

Use the energy diagram to answer Questions 21–23.

The two graphs below represent the same chemical reaction under different conditions.



21. **Interpreting Data** How does the energy of the products compare with the energy of the reactants?
22. **Classifying** Tell whether this reaction is exothermic or endothermic.
23. **Applying Concepts** What change in condition might account for the lower "hump" in the second graph? Explain.

Lab zone Chapter Project

Performance Assessment Make a poster of your test results. Display your reaction chamber for the class. Discuss how your chamber was built to the specifications agreed upon by the class. Describe its safety features. Based on your results, rate how effectively your chamber works as a closed system.

Standardized Test Prep

Test-Taking Tip

Watching for Qualifiers

Many multiple-choice questions use qualifiers such as the words *best, except for, most,* and *least.* For example, you might be asked what is the *best* method for determining the density of a liquid. When you answer that kind of question, you need to read all the answer choices very carefully. Some of the answers may be correct, but not the best answer. In another question you may be told that a particular condition is satisfied by all the answer choices *except for* one. If you read the question too quickly, you may miss this two-word qualifier. In this type of question, the incorrect statement is actually the correct answer choice.

Sample Question

Each chemical equation below is correctly balanced *except for*

A $NaOH + HCl \longrightarrow NaCl + H_2O$
B $SO_3 + H_2O \longrightarrow H_2SO_4$
C $AgNO_3 + H_2S \longrightarrow Ag_2S + HNO_3$
D $Fe + H_2SO_4 \longrightarrow FeSO_4 + H_2$

Answer

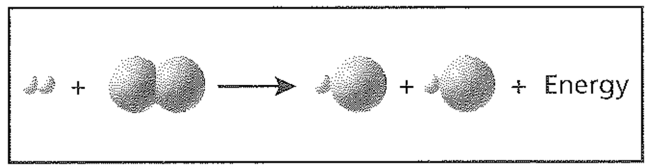
The correct answer is **C**. A balanced chemical equation shows the same number of each type of atom on both sides of the equation. The left side of the equation shows a total of 1 Ag, 1 N, 3 O, 2 H, and 1 S. The right side shows 1 N and 3 O, but 2 Ag and only 1 H, so the equation is not balanced.

Choose the letter of the best answer.

1. Which of the following is the *best* evidence for a chemical reaction?
   A gas bubbles
   B formation of a new substance
   C change of state
   D change in temperature

2. Which shows a balanced chemical equation for the decomposition of aluminum oxide (Al_2O_3)?
   F $Al_2O_3 \longrightarrow 2\,Al + O_2$
   G $Al_2O_3 \longrightarrow 2\,Al + 3\,O_2$
   H $2\,Al_2O_3 \longrightarrow 4\,Al + O_2$
   J $2\,Al_2O_3 \longrightarrow 4\,Al + 3\,O_2$

Base your answers to Questions 3 and 4 on the diagram below. The diagram represents molecules of two different elements that are gases. The elements react chemically to produce a third gas.



3. The diagram represents a(n)
   A endothermic reaction in which energy is released.
   B exothermic reaction in which energy is absorbed.
   C exothermic reaction in which energy is released.
   D reaction in which energy is destroyed.

4. What can be inferred from the diagram?
   F Matter is not created or destroyed in a chemical reaction.
   G The rate of a reaction depends on the surface area of the reactants.
   H A gas molecule always consists of two identical atoms.
   J The product is carbon monoxide gas.

Constructed Response

5. Zinc metal (Zn) reacts with hydrochloric acid (HCl) to produce hydrogen gas (H_2) and zinc chloride ($ZnCl_2$). A scientist has powdered zinc and a chunk of zinc of equal mass. Available in the lab are dilute HCl and concentrated HCl. Which combination of zinc and acid would react most quickly? Explain why the combination you chose would make the reaction occur most quickly.