

## 3.1

## KEY CONCEPT

## Chemical reactions alter arrangements of atoms.

## BEFORE, you learned

- Atoms of one element differ from atoms of all other elements
- Chemical bonds hold compounds together
- Chemical bonds may be ionic or covalent

## NOW, you will learn

- About chemical changes and how they occur
- About three types of chemical reactions
- How the rate of a chemical reaction can be changed

## VOCABULARY

chemical reaction p. 69

reactant p. 71

product p. 71

precipitate p. 72

catalyst p. 76

## EXPLORE Chemical Changes

## How can you identify a chemical change?

## PROCEDURE

- 1 Pour about 3 cm (1 in.) of vinegar into the bowl. Add a spoonful of salt. Stir until the salt dissolves.
- 2 Put the pennies into the bowl. Wait two minutes, and then put the nail into the bowl.
- 3 Observe the nail after five minutes and record your observations.

## MATERIALS

- vinegar
- clear bowl
- plastic spoon
- table salt
- 20 pennies
- large iron nail



## WHAT DO YOU THINK?

- What did you see on the nail? Where do you think it came from?
- Did a new substance form? What evidence supports your conclusion?



## Atoms interact in chemical reactions.

You see substances change every day. Some changes are physical, such as when liquid water changes to water vapor during boiling. Other changes are chemical, such as when wood burns to form smoke and ash, or when rust forms on iron. During a chemical change, substances change into one or more different substances.

A **chemical reaction** produces new substances by changing the way in which atoms are arranged. In a chemical reaction, bonds between atoms are broken and new bonds form between different atoms. This breaking and forming of bonds takes place when particles of the original materials collide with one another. After a chemical reaction, the new arrangements of atoms form different substances.

## COMBINATION NOTES

Use combination notes to organize information about how atoms interact during chemical reactions.

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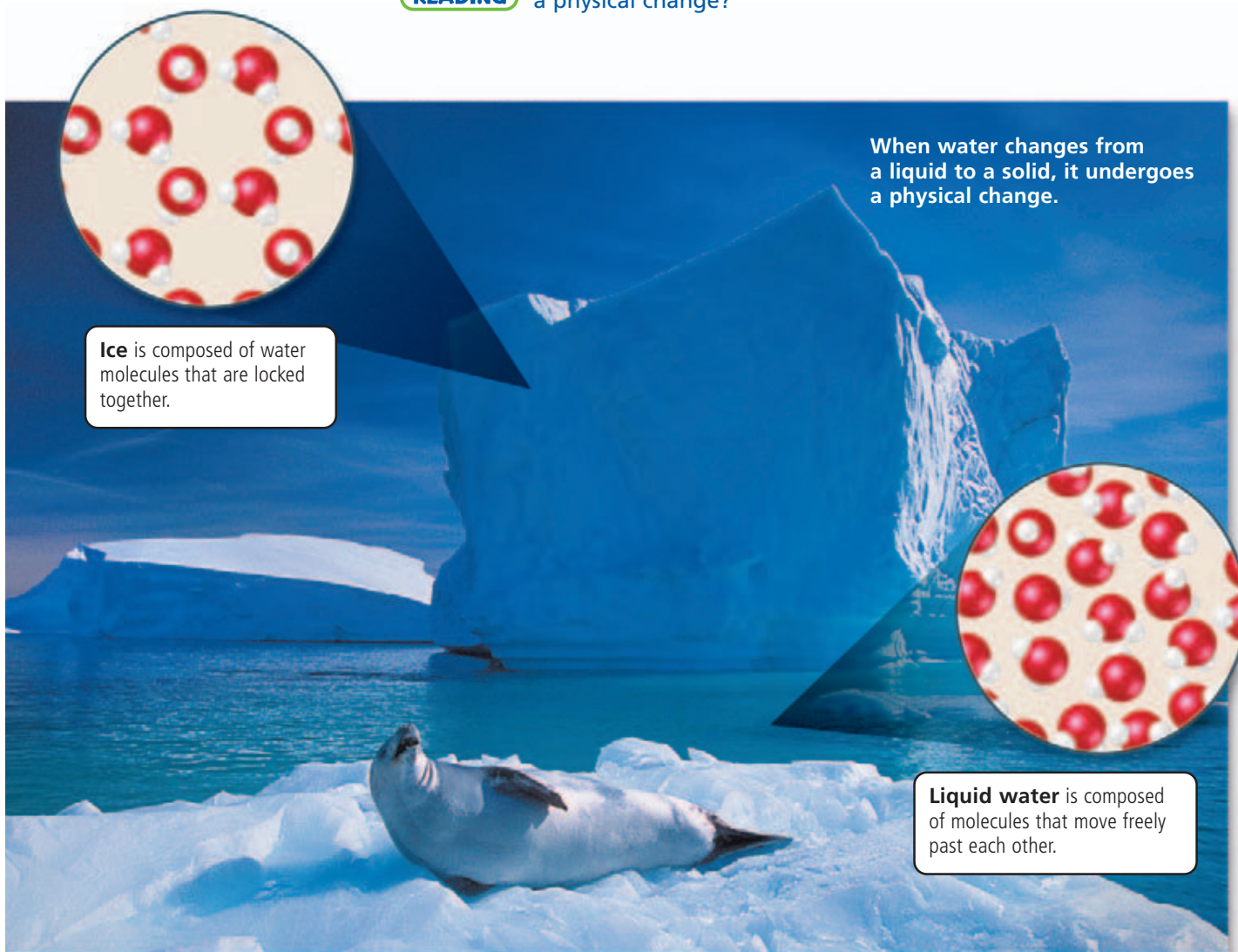
## Physical Changes

A change in the state of a substance is an example of a physical change. The substance may have some different properties after a physical change, but it is still the same substance. For example, you know that water can exist in three different physical states: the solid state (ice), the liquid state (water), and the gas state (water vapor). However, regardless of what state water is in, it still remains water, that is,  $\text{H}_2\text{O}$  molecules. As ice melts, the molecules of water move around more quickly, but the molecules do not change. As water vapor condenses, the molecules of water move more slowly, but they are still the same molecules.

Substances can undergo different kinds of physical changes. For example, sugar dissolves in water but still tastes sweet because the molecules that make up sugar do not change when it dissolves. The pressure of helium changes when it is pumped from a high-pressure tank into a balloon, but the gas still remains helium.

### CHECK YOUR READING

What happens to a substance when it undergoes a physical change?



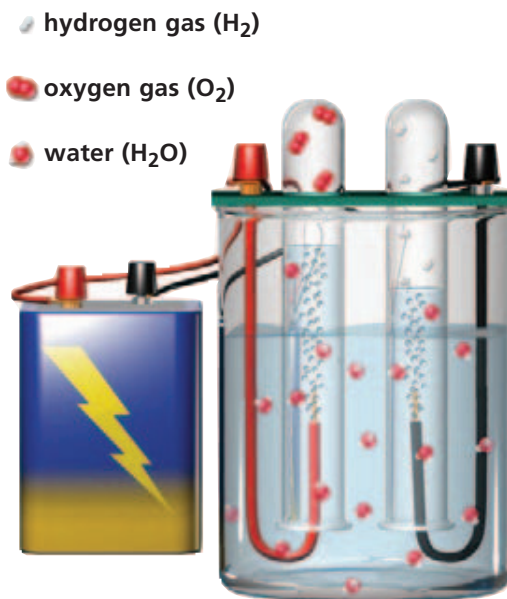
## Chemical Changes

Water can also undergo a chemical change. Water molecules can be broken down into hydrogen and oxygen molecules by a chemical reaction called electrolysis. When an electric current is passed through liquid water ( $\text{H}_2\text{O}$ ), it changes the water into two gases—hydrogen and oxygen. The molecules of water break apart into individual atoms, which then recombine into hydrogen molecules ( $\text{H}_2$ ) and oxygen molecules ( $\text{O}_2$ ). The original material (water) changes into different substances through a chemical reaction.

Hydrogen and oxygen are used as rocket fuel for the space shuttle. During liftoff, liquid hydrogen and liquid oxygen are combined in a reaction that is the opposite of electrolysis. This reaction produces water and a large amount of energy that helps push the shuttle into orbit.

**CHECK YOUR READING** How does a chemical change differ from a physical change?

### Electrolysis of Water



Water molecules can be split apart to form separate hydrogen and oxygen molecules.

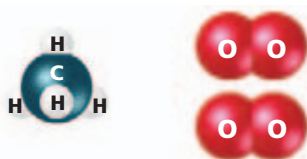
## Reactants and Products

**Reactants** are the substances present at the beginning of a chemical reaction. In the burning of natural gas, for example, methane ( $\text{CH}_4$ ) and oxygen ( $\text{O}_2$ ) are the reactants in the chemical reaction. **Products** are the substances formed by a chemical reaction. In the burning of natural gas, carbon dioxide ( $\text{CO}_2$ ) and water ( $\text{H}_2\text{O}$ ) are the products formed by the reaction. Reactants and products can be elements or compounds, depending on the reaction taking place.

During a chemical reaction, bonds between atoms in the reactants are broken and new bonds are formed in the products. When natural gas is burned, bonds between the carbon and hydrogen atoms in methane are broken, as are the bonds between the oxygen atoms in oxygen molecules. New bonds are formed between carbon and oxygen in carbon dioxide gas and between hydrogen and oxygen in water vapor.

#### Reactants—bonds broken

methane + oxygen  
( $\text{CH}_4$ )      ( $\text{O}_2$ )



#### Products—new bonds formed

carbon dioxide + water  
( $\text{CO}_2$ )      ( $\text{H}_2\text{O}$ )



**CHECK YOUR READING** What must happen for reactants to be changed into products?



## Evidence of Chemical Reactions

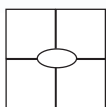
Some chemical changes are easy to observe—the products formed by the rearrangement of atoms look different than the reactants. Other changes are not easy to see but can be detected in other ways.

**Color Change** Substances often change color during a chemical reaction. For example, when gray iron rusts the product that forms is brown, as shown in the photograph below.

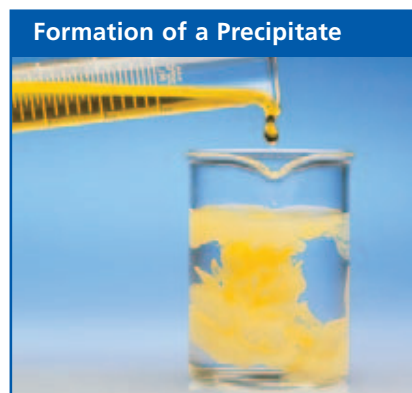
**Formation of a Precipitate** Many chemical reactions form products that exist in a different physical state from the reactants. A solid product called a **precipitate** may form when chemicals in two liquids react, as shown in the photograph below. Seashells are often formed this way when a sea creature releases a liquid that reacts with seawater.

### VOCABULARY

Remember to use a four square diagram for *precipitate* and other vocabulary terms.



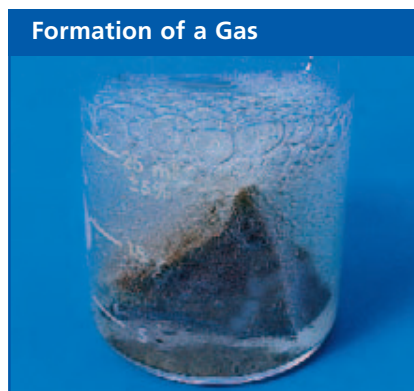
Color Change



Formation of a Precipitate

**Formation of a Gas** Chemical reactions may produce a gas, like that often formed when antacid pills are mixed with excess stomach acid. The photograph below shows an example in which carbon dioxide gas is produced by a chemical reaction.

**Temperature Change** Most chemical reactions involve a temperature change. Sometimes this change can be inferred from the observation of a flame, as in the burning of the metal magnesium in the photograph below. Other temperature changes are not immediately obvious. If you have touched concrete before it hardens, you may have noticed that it felt warm. This warmth is due to a chemical reaction.



Formation of a Gas



Temperature Change

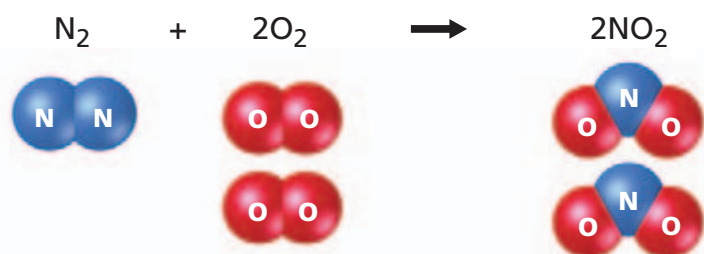
## Chemical reactions can be classified.

Scientists classify chemical reactions in several ways to help make the different types of reactions easier to understand. All reactions form new products, but the ways in which products are made can differ.

**Synthesis** In a synthesis reaction, a new compound is formed by the combination of simpler reactants. For example, nitrogen dioxide ( $\text{NO}_2$ ), a component of smog, forms when nitrogen and oxygen combine in the air.

### READING TIP

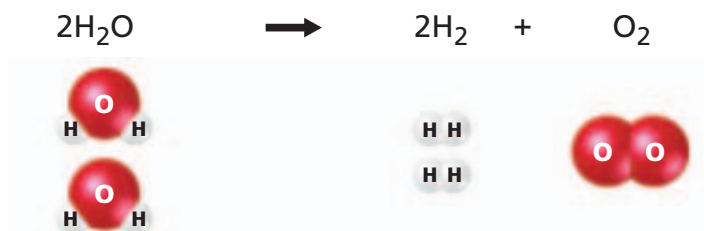
*Synthesis* means “making a substance from simpler substances.”



**Decomposition** In a decomposition reaction, a reactant breaks down into simpler products, which could be elements or other compounds. Decomposition reactions can be thought of as being the reverse of synthesis reactions. For example, water can be decomposed into its elements—hydrogen and oxygen.

### READING TIP

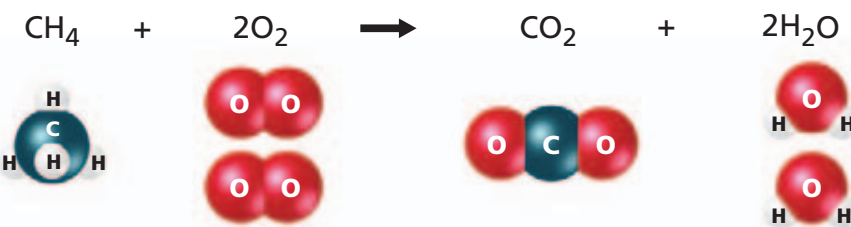
*Decomposition* means “separation into parts.”



**Combustion** In a combustion reaction, one reactant is always oxygen and another reactant often contains carbon and hydrogen. The carbon and hydrogen atoms combine with oxygen, producing carbon dioxide and water. The burning of methane is a combustion reaction.

### READING TIP

Combustion is the process of burning with oxygen.



### CHECK YOUR READING

How are synthesis reactions different from decomposition reactions?

## The rates of chemical reactions can vary.

Most chemical reactions take place when particles of reactants collide with enough force to react. Chemical reactions can occur at different rates. Striking a match causes a very quick chemical reaction, while the rusting of an iron nail may take months. However, the rate of a reaction can be changed. For instance, a nail can be made to rust more quickly. Three physical factors—concentration, surface area, and temperature—and a chemical factor—a catalyst—can greatly affect the rate of a chemical reaction.



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Observe how changing the concentration of a reactant can change the rate of a reaction.

### Concentration

Concentration measures the number of particles present in a certain volume. A high concentration of reactants means that there is a large number of particles that can collide and react. Turning the valve on a gas stove to increase the flow of gas increases the concentration of methane molecules that can combine with oxygen in the air. The result is a bigger flame and a faster combustion reaction.

### Surface Area

Suppose one of the reactants in a chemical reaction is present as a single large piece of material. Particles of the second reactant cannot get inside the large piece, so they can react only with particles on the surface. To make the reaction go faster, the large piece of material could be broken into smaller pieces before the reaction starts.

## INVESTIGATE Chemical Reactions

### How can the rate of a reaction be changed?

#### PROCEDURE

- 1 Place a whole seltzer tablet in one cup. Crush the second tablet and place it in the second cup.
- 2 Fill each cup halfway with water.
- 3 Time how long the tablet in each cup fizzes.

#### WHAT DO YOU THINK?

- How long did the whole tablet fizzle? What about the crushed tablet?
- How are these results related to the rate of a chemical reaction? Explain.

**CHALLENGE** How might your results be related to collisions between particles during a chemical reaction?

#### SKILL FOCUS Inferring



#### MATERIALS

- 2 seltzer tablets
- 2 plastic cups
- tap water
- stopwatch

#### TIME

15 minutes



Breaking a large piece of material into smaller parts increases the surface area of the material. All of the inner material has no surface when it is inside a larger piece. Each time the large piece is broken, however, more surfaces are exposed. The amount of material does not change, but breaking it into smaller parts increases its surface area. Increasing the surface area increases the rate of the reaction.

**CHECK YOUR READING** Why does a reaction proceed faster when the reactants have greater surface areas?

## Temperature


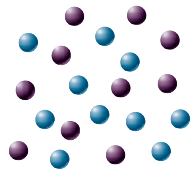
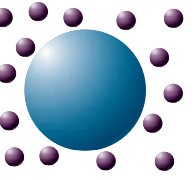
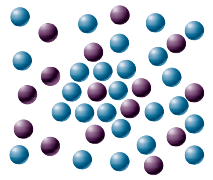
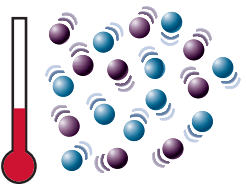
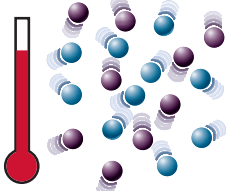
The rate of a reaction can be increased by making the particles move faster. The result is that more collisions take place per second and occur with greater force. The most common way to make the particles move faster is to add energy to the reactants, which will raise their temperature.

Many chemical reactions during cooking go very slowly, or do not take place at all, unless energy is added to the reactants. Too much heat can make a reaction go too fast, and food ends up burned. Chemical reactions can also be slowed or stopped by decreasing the temperature of the reactants. Again, think about cooking. The reactions that take place during cooking can be stopped by removing the food from the heat source.

### REMINDER

Temperature is the average amount of kinetic energy of the particles in a substance.

### Particles and Reaction Rates

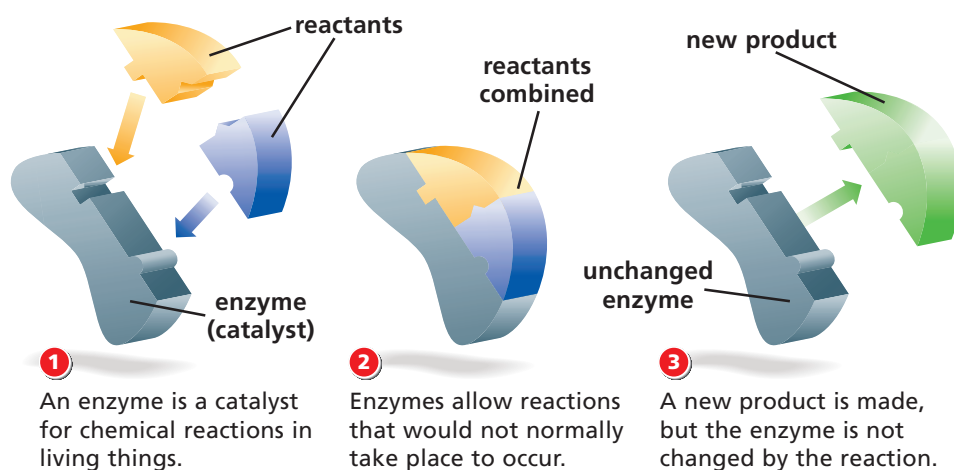
Changes in Reactants	Normal Reaction Rate	Increased Reaction Rate
<b>Concentration</b> An increase in concentration of the reactants increases the number of particles that can interact.		
<b>Surface area</b> An increase in the surface area of the reactants increases the number of particles that can interact.		
<b>Temperature</b> Adding energy makes particles move faster and increases temperature. The increase in motion allows reactants to collide and react more frequently.		

## RESOURCE CENTER CLASSZONE.COM

Learn more about catalysts and how they work in living things.

## Catalysts

The rate of a reaction can be changed chemically by adding a catalyst. A **catalyst** is a substance that increases the rate of a chemical reaction but is not itself consumed in the reaction. This means that after the reaction is complete, the catalyst remains unchanged. Catalysts are very important for many industrial and biological reactions. In fact, many chemical reactions would proceed slowly or not take place at all without catalysts.



In living things, catalysts called enzymes are absolutely necessary for life. Without them, many important reactions could not take place under the conditions within your body. In fact, in 2003, scientists reported that they had discovered the slowest known chemical reaction in living things. This reaction would normally take one trillion years. Enzymes, though, allow the reaction to occur in 0.01 seconds.

### CHECK YOUR READING

Why are catalysts important in chemical reactions?

## 3.1 Review

### KEY CONCEPTS

- How do physical changes differ from chemical changes? Explain.
- Describe four types of evidence of a chemical reaction.
- Describe the ways in which the rate of a chemical reaction can be changed.

### CRITICAL THINKING

- Synthesize** What evidence shows that the burning of methane is a chemical reaction?
- Compare** What about combustion reactions makes them different from either synthesis or decomposition reactions?

### CHALLENGE

- Apply** How might the chewing of food be related to the rate of a chemical reaction—digestion—that occurs in your body? Explain.