3.2.1 *Reactants and Products*

OBJECTIVES

- Identify the parts of a chemical reaction.
- Specify the five indicators of a chemical reaction.

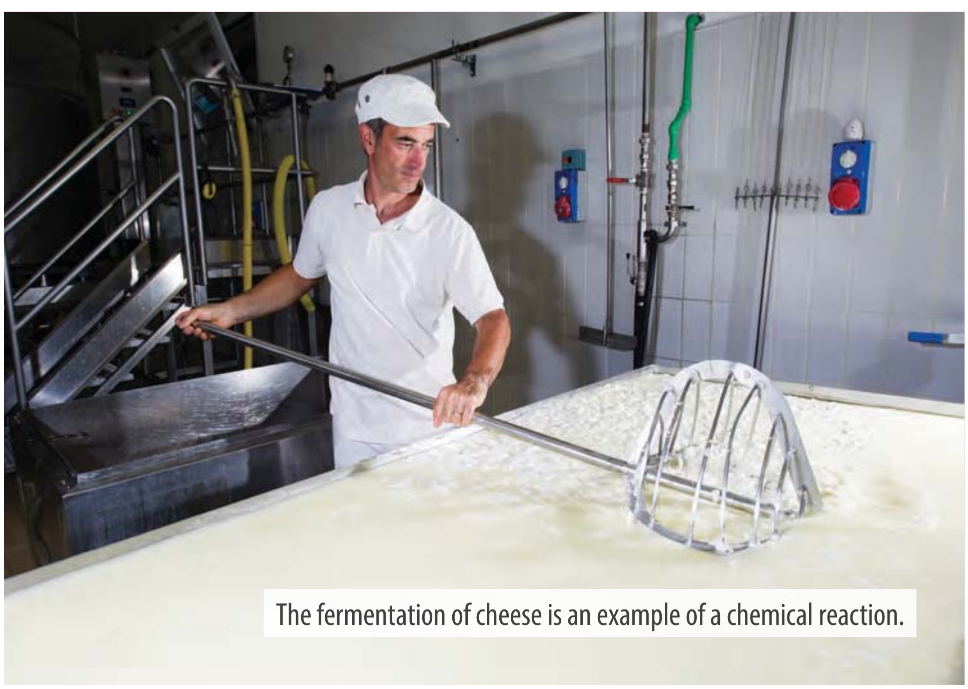
VOCABULARY

- **chemical reaction** the process in which one or more substances are transformed into different substances
- **product** a new substance that is formed following a chemical reaction
- **reactant** a substance that is present before a chemical reaction that then undergoes changes during a chemical reaction

Chemical reactions are happening all around you. The trees outside may not look like they are doing very much, but they are actually busy converting carbon dioxide and water into food through the process called *photosynthesis*. Similarly, your cells are converting oxygen into a usable form of energy that allows your muscles to contract and your brain to function. The formation of rust, the exploding volcano model in a science fair, the fermentation of cheese and yogurt, and the burning of wood in a fireplace are all examples of chemical reactions.

A **chemical reaction** is the process in which one or more substances are transformed into different substances. But not all chemical interactions are reactions. When liquid water freezes and becomes ice, the water molecules are not transformed into a different substance. They are still water molecules. This is an example of a physical change. A chemical change must occur for the interaction to be considered a reaction. During a chemical reaction, atoms and molecules collide. The force of the collisions causes the molecular bonds to break. New bonds are formed and new substances are created.

Chemical reactions are comprised of two main parts: reactants and products. **Reactants** are substances that are present before a chemical reaction and undergo changes during a chemical reaction. **Products** are the new substances that are formed following a chemical reaction. For example, rust (iron oxide) is the product of the reaction between iron and oxygen, which are



The fermentation of cheese is an example of a chemical reaction.

the reactants. During this reaction, the bonds that hold the oxygen atoms together are broken. New bonds form between the oxygen atoms and the iron atoms.

Reactants		Product
Iron + Oxygen	⟶	Iron oxide

If reactions were written in word form only, they would be very cumbersome to read. For example, the photosynthesis reaction could be written as follows: six units of carbon dioxide react with six units of dihydrogen monoxide to produce one unit of glucose and six units of diatomic oxygen. Scientists created chemical equations to simplify reaction descriptions. Chemical equations include the formula and quantity of each reactant and product. The chemical equation of the photosynthesis reaction is written as follows:

$$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$$

Unlike the chemical interaction of liquid water becoming ice, the products of a chemical reaction have completely different properties compared to the reactants. For example, chlorine is a poisonous green gas, and sodium is a metal that reacts

TRY THIS

Fizzy Water

Fill a clear plastic bottle half full with vegetable oil. Add enough water to fill another quarter of the bottle. Using a pipette, place a few drops of food coloring in the mixture. Place the cap on the bottle, and shake until the food coloring is thoroughly mixed with the water. Do not disturb the bottle for a couple of minutes until the oil and water layers completely separate. Drop an effervescent tablet into the bottle and observe. Did a reaction occur? How do you know?

BIOGRAPHY

John Edward Hodge

Chemist John Edward Hodge was born in Kansas City, Kansas, on October 12, 1914. As a boy, he participated in model airplane contests and became an expert at billiards. He graduated Phi Beta Kappa from the University of Kansas, earned his master's degree, and pursued postgraduate studies at Bradley University and the Federal Executive Institute. He began his career as a chemist for the oil industry before becoming a professor of chemistry at Western University in Quindaro, Kansas. In 1941, Hodge began his 40-year career for the USDA at the Northern Regional Research Center, in Peoria, Illinois. Hodge analyzed the Mailliard reaction, the browning that takes place in foods such as bread or marshmallows when they are heated. Hodge correctly pointed out the connection between non-enzymatic browning and flavor intensity in foods, which changed cooking methods and the food industry. His paper on food browning remains the most cited work in the fields of food science and food chemistry. Hodge was passionate about encouraging black students to pursue careers in chemistry, and recruited many minority students as summer interns.

Chemical Reaction Indicators

Color change

Formation of a precipitate

Formation of a gas

Noticeable odor

Release of light or sound energy

explosively with water. When these substances interact and undergo a chemical reaction, the product is table salt. This product is neither explosive in water nor poisonous. Under ordinary circumstances, table salt will not separate into chlorine and sodium. The behavior of the products of chemical reactions truly shows God's wisdom. Imagine what would happen if the salt sprinkled on food suddenly took on the properties of chlorine and sodium!

There are five indicators that signify a reaction has occurred. The first indicator that a reaction has occurred is a change in color. Iron is a silver-white metal. When it reacts with oxygen, a brownish-red layer of rust is produced. Another way to recognize a reaction is by the formation of a precipitate. When two liquid substances combine, they may form a new solid substance called *a precipitate*. Typically, these liquid substances are ionic compounds. When the ionic compounds dissolve, their ions separate. Some of the ions remain dissolved in the solution. Others combine with different ions to form new solid compounds (precipitates) that do not dissolve in water. Reactions are also observed with the formation of a gas. The appearance of bubbles, which is carbon dioxide, when baking soda and vinegar are combined indicates a reaction has taken place. A noticeable odor is the fourth indicator of a reaction. When an egg begins to rot, a pungent odor is produced. This means that a reaction inside the egg has taken place. The fifth indicator that a reaction has occurred is the release of energy in the form of light or sound. Colorful fireworks release both forms of energy when they explode.

LESSON REVIEW

1. Describe photosynthesis as a reaction.
2. What are the reactants in the following cake recipe: 2 cups sugar, 1¾ cups flour, ¾ cup cocoa, 1½ tsp baking powder, 1½ tsp baking soda, 1 tsp salt, 2 eggs, 1 cup milk, ½ cup vegetable oil, 2 tsp vanilla extract, and 1 cup boiling water?
3. Does a reaction occur when berries are mashed and made into jam? Explain.
4. What are the five indicators that signify a reaction has occurred? Give one example of a reaction that includes one of these indicators.

BIBLE CONNECTION

Mass Conservation, Loaves, and Fish

Jesus fed thousands of people more than once with only a few loaves of bread and a couple of fish. How can 5,000 people be fed with five loaves of bread and two fish as recorded in Matthew 14? Is this even possible if all reactions are governed by the law of conservation of mass? Jesus performed a miracle after giving thanks to the Father. Laws are created by men in an attempt to describe God's creation. Given that God is the Creator, He has the power and authority to surpass human-made laws.

LAWS & PRINCIPLES

Henry's Law

The amount of a gas that will dissolve in a liquid is directly proportional to the pressure applied to that gas. The more pressure applied, the more gas that dissolves into the solvent.

HISTORY

Tesla, Edison, and Westinghouse

George Westinghouse

Throughout history, there have been many rivalries in the science sector. One of the most notable rivalries occurred between Thomas Edison and George Westinghouse. In the United States, there was a race to provide electricity across the country. Edison developed a system that used direct current (DC). Westinghouse created a system that offered electricity through alternating currents (AC). This battle was known as *The War of Currents*. There were some limitations to DC systems that Edison recognized. The main limitation was the difficulty to transmit direct currents over large areas without significant energy loss. He enlisted the help of Nikola Tesla to design a better power transmission system. Tesla indicated that the best way would be to use alternating currents because they contain high-voltage energy that could be delivered over large areas without using an excessive amount of current. Edison discounted Tesla's ideas. Tesla stopped working for Edison in 1885 and sold some of his patents to Westinghouse. This shift in production led to the expansion of Westinghouse Electric AC generators. In an effort to ruin Westinghouse, Edison strongly promoted the idea that AC generators were extremely unsafe and could cause incidents of electrocution. By 1893, despite all of Edison's attempts, Westinghouse became the industry leader in electricity.

CHALLENGE

Conflicting Dates

Permian coalified bark found in Sydney, Australia, yielded a radiocarbon date of 33,700 years. If carbon-14 has a half-life of 5,730 years and fossils of wood found in Permian layers of rock are considered to be hundreds of millions of years old, why do these fossils have measurable amounts of carbon-14?

TRY THIS

Heat by Radiation

Refrigerate a beaker of water. When it is chilled, take it out of the refrigerator and measure the water's temperature. Place it in direct sunlight on a windowsill. Keep the thermometer in the water and observe the heat added by the sun's radiant energy as measured by the temperature change on the thermometer. What is heat? What direction did the heat travel? How much did the temperature of the water change? What happened to the molecules in the water?

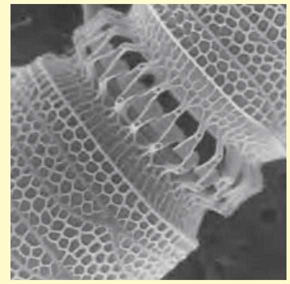
WORLDVIEW

- During the 15th century, an Asian artist invented a technique called *Kintsugi*. Artists who practice this skill take pieces of what some consider worthless material and mend the broken pieces with precious metals. The material they use to mend the pieces makes the product very valuable. Much in the same way, scientists join compounds to create synthetic materials that are valued more than the component elements. People sometimes experience brokenness, as well. But, those who love and trust God can be reassured that He will mend their brokenness. The Holy Spirit joins the broken pieces to create a spirit that is more beautiful and valuable than could ever be imagined. The writer of Psalm 73:25–26 expresses this idea in the following way: "Whom have I in heaven but You? And Earth has nothing I desire besides You. My flesh and my heart may fail, but God is the strength of my heart and my portion forever."

Features found in the Student and Teacher Editions.

FYI

Nanotechnology


Nanotube

Nanotechnology is a fast-growing field of study. Nano scientists seek to operate and manufacture materials and devices that are the size of atoms or small groups of atoms. Materials at the nanoscale are unique because they often have distinct physical and chemical properties. For example, gold that is normally nonreactive is extremely reactive at the nanoscale. Scientists from many fields—physics, biology, chemistry, materials science, and engineering—want to utilize these unique features to create materials that require less energy to manufacture, produce less waste, and ultimately improve health, safety, conservation efforts, and quality of life.

Many of the materials that scientists have manufactured on the nanoscale were inspired by God's handiwork. They demonstrate His extreme efficiency, precision, and power. Some examples include enzymes and catalysts, DNA, and linear and rotary molecular motors that carry out muscle contractions. Scientists have created "nanowhiskers" that are about 10 nm long and are hooklike. They prevent stains on natural and synthetic fibers. Some nanocrystals create invisible sunscreens that block ultraviolet light. Others are incorporated into bandages to prevent infection and kill harmful bacteria. The medical field has particularly benefited from the field of nanotechnology. Some options include drugs that can be delivered to a specific location and released at predetermined times for optimal treatment. Other scientists are working on retinal implants and neural probes that can be implanted into brain tissue to activate and control motor functions.

CAREER

Nuclear Engineer

Nuclear engineers work with nuclear power and radiation. Some use their knowledge of nuclear energy to design, develop, monitor, and operate nuclear power plants that generate electricity and that power naval vessels. Others may work on the nuclear fuel cycle, which involves producing, handling, and using nuclear fuel and safely disposing of nuclear waste. Or, they may focus on fusion energy research. Nuclear engineers may also specialize in developing nuclear power sources for spacecraft or developing medical uses for radioactive materials to diagnose and treat diseases.

Nuclear engineers are exposed to radiation, but they wear protective gear. This gear includes a badge that indicates the amount of radiation exposure and warns of overexposure.

BIOGRAPHY

Shirley Ann Jackson

Shirley Ann Jackson is a woman of many firsts. She is the first African-American woman to receive a doctorate from the Massachusetts Institute of Technology. Jackson earned her degree in theoretical physics. Her specialty was in condensed matter physics, specifically layered systems and the physics of opto-electronic materials. She is also the first African-American woman to be president of Rensselaer Polytechnic Institute—the oldest technological research university in the United States. Jackson is the first African-American woman to be elected president and chairman of the board of the American Association for the Advancement of Science (AAAS). She has assisted members of the White House in formulating scientific and technological policies. Her work helped to strengthen the economy and provide more employment and innovation opportunities for many people. She also served as the Chairman of the US Nuclear Regulatory Commission. In this capacity, Jackson helped to license, regulate, and safeguard the use of nuclear reactor by-product materials. She was awarded the National Medal of Science in 2016. Jackson's drive and passion for science prompted her to encourage other students, specifically women and ethnic minorities, to pursue scientific study. Some consider her the ultimate role model for women in science.

SCIENCE IN ACTION

How to Jump-Start a Car Battery

Imagine turning the ignition switch and nothing happens. You hear a few clicks, but the car will not start. It is probably a dead battery. How will you get to school to take final exams? Then, you remember the jumper cables in the trunk of the car. But, what is the right way to connect the cables to the car's battery? It is important to remember that jumper cables with a low gauge value indicate greater strength. The standard jumper cable size is a gauge of six. Also, some cars require extra steps in order to have a successful jump. Consult the car manual first to see if the car will permit a jump. It is always important to utilize safe practices when handling jumper cables. Once the cables are connected to a battery, never touch the metal clamps to anything other than the intended vehicle target. Here are the steps to follow to get the car running again:

1. Position two cars so they are facing each other but not touching. Ideally, they will be separated by a distance of about 45 centimeters.
2. Place automatic transmission cars in park and manual transmission cars in neutral. Set the parking brakes.
3. Both cars should be turned off with the keys removed from the ignition.
4. Open the hood of both cars and locate the batteries' terminals. For each battery, there will usually be both a positive and a negative symbol located near the terminals.
5. Attach the red, positive cable clamp to the positive battery terminal of the dead battery.
6. Attach the other red, positive cable clamp to the positive battery terminal of the car that is functioning.
7. Connect the black, negative cable clamp to the negative battery terminal of the car that is functioning.
8. Attach the other black, negative cable clamp to an unpainted, metal part of the car with the dead battery, such as a nut on the engine block. Do not connect the negative cable clamp to the dead battery.
9. Start the functioning car. It may be helpful to wait a few minutes before attempting to start the car with the dead battery.
10. After a few minutes, try starting the car with the dead battery. If the car does not start right away, wait a few more minutes and try again. Revving the functioning car's engine may also help revive the dead battery.
11. Once the car that had a dead battery is running, disconnect the jumper cables. Remove the black, negative cable clamps first. Do not let the clamps touch each other.
12. Drive the car that had a dead battery for at least 15 minutes to build up a charge in the battery. This will help prevent the battery from dying again once the car is shut off.