Section 1
Forming New Substances

Key Concept During chemical reactions, atoms rearrange to form new substances that have different properties than the original substances had.

What You Will Learn
- Four signs that indicate that a chemical reaction may be taking place are a change in color, the formation of a gas, the formation of a precipitate, and a change in energy.
- Chemical reactions produce new substances whose chemical and physical properties differ from the properties of the original substances.
- In a chemical reaction, chemical bonds break and atoms rearrange.
- Chemical reactions absorb or release energy.

Why It Matters
Understanding chemical reactions will help you understand changes that happen around you every day.

Do you know why tree leaves change color in the fall? Leaves are green because they contain a colored substance, or *pigment*. This green pigment is called *chlorophyll* (KLAWR uh FIL). During the spring and summer, the leaves have a large amount of chlorophyll in them. But in the fall, when temperatures drop and there are fewer hours of sunlight, trees stop making chlorophyll molecules. The chlorophyll in the leaves breaks down to form new substances. The green chlorophyll is no longer present to hide the other pigments. So, you can see the orange and yellow colors of the other pigments.

Chemical Reactions
A chemical change takes place when chlorophyll breaks down into new substances. This change is an example of a chemical reaction. A **chemical reaction** is a process in which one or more substances change to make one or more new substances. The chemical and physical properties of the new substances differ from those of the original substances. Some results of chemical reactions are shown in **Figure 1.**

Figure 1 Results of Chemical Reactions

When you mix water with baking powder, substances in the baking powder react to form bubbles of carbon dioxide gas. These bubbles give the muffin its spongelike texture.

Leaves change color in the fall as a result of chemical changes in the leaves.

Signs of Chemical Reactions

How can you tell when a chemical reaction is taking place? **Figure 2** shows some signs that tell you that a reaction may be taking place. Some reactions form solid precipitates. A **precipitate** is a solid substance that forms in a solution. In other chemical reactions, gas bubbles form. Some reactions make new substances that have different colors than the starting substances did. During other chemical reactions, energy is given off. This energy may be in the form of light, heat, or electrical energy. Reactions often have more than one of these signs. The more signs that you see, the more likely it is that a chemical reaction is taking place.

Figure 2 Some Signs of Chemical Reactions

Gas Formation
The chemical reaction in the beaker has formed a brown gas, nitrogen dioxide. This gas forms when a strip of copper is placed into nitric acid.

Solid Formation
Here you see potassium chromate solution being added to a silver nitrate solution. The dark red solid is a precipitate of silver chromate.

Energy Change
Energy is released during some chemical reactions. The fire in this photo gives off energy in the form of light and heat. During other chemical reactions, energy is taken in.

Color Change
Don't spill chlorine bleach on your jeans! The bleach reacts with the blue dye on the fabric and causes the color of the material to change.

Standards Check What is a precipitate?

A Change of Properties

Even though the signs we look for to see if a reaction is taking place are good signals of chemical reactions, they do not guarantee that a reaction is happening. For example, gas can be given off when a liquid boils. But boiling is a physical change, not a chemical reaction.

So, how can you be sure that a chemical reaction is happening? The most important sign is the formation of new substances that have new properties. In **Figure 3,** the starting materials in the reaction are sugar and sulfuric acid. Several signs tell you that a chemical reaction is taking place. Bubbles form, which tells you that a gas is given off. The beaker becomes very hot. But most important, new substances form. And the properties of these substances are very different from those of the starting substances.

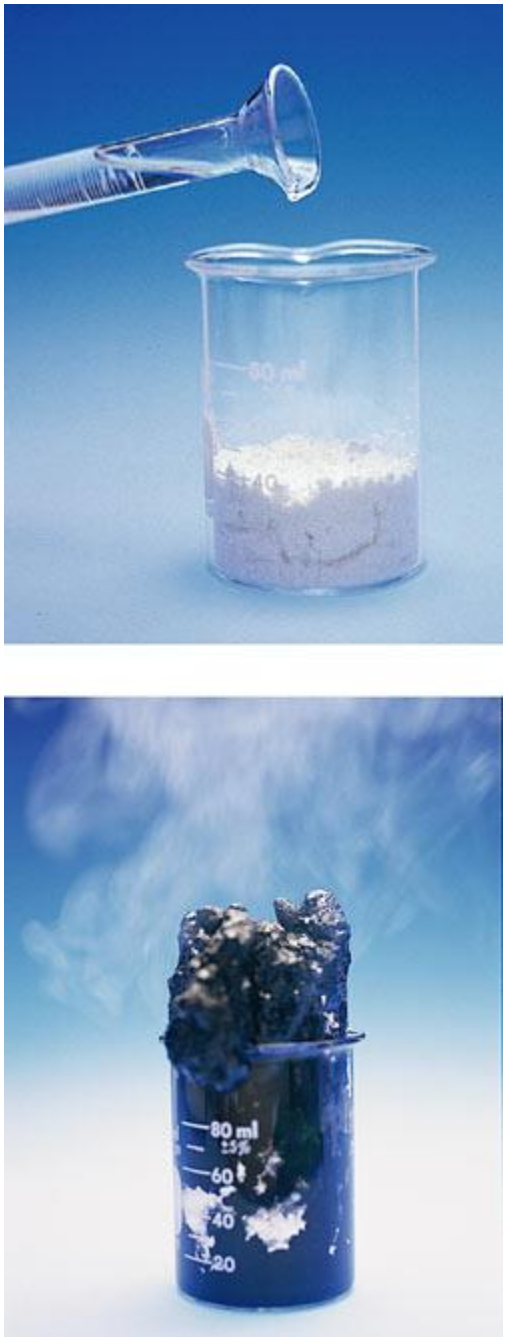

Figure 3 The top photo shows table sugar, a white solid, being mixed with sulfuric acid, a clear liquid. These two starting substances react to form new substances that are very different from the sulfuric acid or sugar. **What are some of the properties of the new substances?**

Bonds: Holding Molecules Together

A *chemical bond* is a force that holds two atoms together in a molecule. For a chemical reaction to take place, the original bonds must break and new bonds must form.

Breaking and Making Bonds

How do new substances form in a chemical reaction? First, chemical bonds in the starting substances must break. Molecules are always moving. If the molecules bump into each other with enough energy, the chemical bonds in the molecules can break. The atoms then rearrange, and new bonds form to make the new substances. **Figure 4** shows how atoms rearrange when hydrogen and chlorine react with each other.

Figure 4 Reaction of Hydrogen and Chlorine

Hydrogen + Chlorine → **Hydrogen chloride**

Breaking Bonds Hydrogen and chlorine are diatomic. Diatomic molecules are two atoms bonded together. The bonds joining these atoms must break before the atoms can react with each other.

Making Bonds A new substance, hydrogen chloride, forms as new bonds are made between hydrogen atoms and chlorine atoms. Hydrogen chloride is also a diatomic molecule.

Standards Check What happens to the bonds of substances during a chemical reaction?

New Bonds, New Substances

What happens when hydrogen and chlorine react? A chlorine gas molecule is a

diatomic (DIE uh TAHM ik) molecule. That is, the molecule is made of two atoms of chlorine. Chlorine gas has a greenish yellow color. Hydrogen gas is also a diatomic molecule. Hydrogen gas is a flammable, colorless gas. When chlorine gas and hydrogen gas react, the bond between the hydrogen atoms breaks. The bond between the chlorine atoms also breaks. A new bond forms between each hydrogen atom and each chlorine atom. A new substance, hydrogen chloride, forms. Hydrogen chloride is a nonflammable, colorless gas. Its properties differ from the properties of both of the starting substances.

Reactions and Energy

Chemical energy is part of all chemical reactions. Energy is needed to break chemical bonds in the starting substances. As new bonds form in the final substances, energy is released. By comparing the chemical energy of the original substances with the chemical energy of the final substances, you can decide if energy is released or absorbed in the overall reaction.

Exothermic Reactions

A chemical reaction in which energy is released is called an **exothermic reaction.** *Exo* means "go out" or "exit." *Thermic* means "heat" or "energy." Exothermic reactions can give off energy in several forms, as **Figure 5** shows. If heat is released in an exothermic reaction, the nearby matter will become warmer. The nearby matter absorbs the heat released by the reaction. The reaction between gasoline and oxygen in a car's engine is an exothermic reaction.

Figure 5 Types of Energy Released in Exothermic Reactions

Light energy is released in the exothermic reaction that is taking place in these light sticks.

Electrical energy is released in the exothermic reaction that will take place in this battery.

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Endothermic Reactions

A chemical reaction in which energy is taken in is called an **endothermic reaction.** *Endo* means "go in." The energy taken in during an endothermic reaction is absorbed from the surroundings. An example of an endothermic process is photosynthesis. In photosynthesis, plants use light energy from the sun to produce glucose molecules. Glucose is a simple sugar that is used as a source of energy for living things.

An endothermic reaction is happening in the flask in **Figure 6.** During the reaction, energy from nearby materials is absorbed. As a result, the flask, the wood block, and the nearby air become cooler. A few drops of water placed between the wood block and the flask become cool enough to freeze. The ice that forms between the flask and the block of wood causes the two objects to stick together.

Figure 6 The reaction in the flask absorbs energy and causes water between the bottom of the flask and the wood to freeze.

Standards Check What is the difference between an endothermic reaction and an exothermic reaction?

The Law of Conservation of Energy

Neither mass nor energy can be created or destroyed in chemical reactions. The **law of conservation of energy** states that energy cannot be created or destroyed. However, energy can change forms. And energy can be transferred from one object to another in the same way that a baton is passed from one runner to another runner.

The energy released in exothermic reactions was first stored in the chemical bonds in the reactants. The energy taken in during endothermic reactions is stored in the products. If you could measure all of the energy in a reaction, you would find that the total amount of energy (of all types) is the same before and after the reaction.

Section Summary

- A chemical reaction is a process by which substances change to form new substances with new chemical and physical properties.
- Signs that indicate a chemical reaction has taken place are a color change, formation of a gas or a solid, and the release or absorption of energy.
- During a reaction, bonds are broken, atoms are re arranged, and new bonds are formed.
- Exothermic reactions give off energy, and endothermic reactions absorb energy.
- The law of conservation of energy states that energy is neither created nor destroyed.