14.2 Types of Reactions

Most of the products you use every day are the result of one or more chemical reactions. As you might imagine, there are many possible chemical reactions. This section provides you with information on how to classify the different types of chemical reactions.

Synthesis reactions

Making compounds

In a **synthesis reaction**, two or more substances combine to form a new compound. A good example of a synthesis reaction is the formation of rust.

$$Fe\,(s) + O_2\,(g) \longrightarrow Fe_2O_3\,(s)$$

From this example, how might you describe the reaction in general terms? The answer to this question is below. In this general equation for a synthesis reaction and the other reactions in this section, A and B represent ions, atoms, or molecules.

$$A + B \longrightarrow AB$$

Polymerization

Recall that a *polymer* is a large molecule made up of repeating segments. **Polymerization**, or the formation of polymers, is a series of synthesis reactions taking place to produce a very large molecule. Polymers are made by joining smaller molecules called *monomers*.

Table 14.1: Polymers

Common Polymers	Polymer Products
polystyrene	foam containers
polyethylene	food packaging
polyester	clothing
polyvinyl chloride	plumbing (PVC pipes)
polyvinyl acetate	chewing gum

VOCABULARY

synthesis reaction - a chemical reaction in which two or more substances combine to form a new compound.

polymerization - the formation of polymers by a series of synthesis reactions.

SCIENCE FACT

Synthesis Reactions and Acid Rain

Some fossil fuels, such as coal, contain sulfur. When these fuels are burned, the sulfur reacts with oxygen in the air to form sulfur dioxide in the following synthesis reaction:

$S\,(s) + O_2\,(g) \rightarrow SO_2\,(g)$

In air polluted with sulfur dioxide, acid rain is produced in the reaction below:

$SO_2\,(g) + H_2O_2\,(g) \rightarrow H_2SO_4\,(aq)$

H_2O_2 is hydrogen peroxide, a substance that is produced in clouds in a reaction between oxygen and water. H_2SO_4 is sulfuric acid.

Decomposition reactions

Breaking down compounds

As you might suspect, chemical reactions are used to make compounds. However, a chemical reaction is also used to break down compounds. A chemical reaction in which a single compound is broken down to produce two or more smaller compounds is called a **decomposition reaction**. The general equation for decomposition is:

$$AB \xrightarrow{Energy} A + B$$

VOCABULARY

decomposition reaction - a chemical reaction in which a compound is broken down into two or more smaller substances.

Energy is required

In most cases, energy is required to get a decomposition reaction going. The most common form of energy used in these chemical reactions is heat. For example, the reaction below was involved in the discovery of oxygen. Heat was used in the decomposition of mercury (II) oxide.

$$2HgO_{(s)} \xrightarrow{Heat} 2Hg_{(l)} + O_{2(g)}$$

For the decomposition of water into hydrogen and oxygen, the energy source is electricity. In fact, this particular reaction, illustrated in Figure 14.13, is called *electrolysis*.

$$2H_2O_{(l)} \xrightarrow{Electricity} 2H_{2(g)} + O_{2(g)}$$

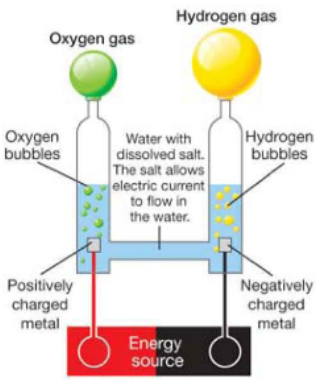


Figure 14.13: *A diagram of the experimental setup for performing the electrolysis of water. Why do you think the balloon for hydrogen gas is twice as big as the one for oxygen gas?*

The number of products formed

The simplest kind of decomposition is the breakdown of a binary compound into its elements. However, larger compounds can also decompose to produce other compounds. The number of compounds that form as products in a decomposition reaction depends on the number of elements in the reactant compound. For example, baking soda ($NaHCO_3$) has four elements. When it undergoes a decomposition reaction with heat, three products form.

$$2NaHCO_{3(s)} \xrightarrow{Heat} 2CO_{2(g)} + H_2O_{(g)} + Na_2O_{(s)}$$

Displacement reactions

Single-displacement reactions

In a **single-displacement reaction**, one element replaces a similar element in a compound. For example, if you place an iron nail into a beaker of copper (II) chloride, you will begin to see reddish copper forming on the iron nail. In this reaction, iron replaces copper in the solution and the copper falls out of the solution onto the nail as a metal.

$$Fe_{(s)} + CuCl_{2(aq)} \longrightarrow FeCl_{2(aq)} + Cu_{(s)}$$

The general equation for a single-displacement reaction is:

$$A + BX \longrightarrow AX + B$$

In this equation, A and B are elements, and AX and BX are compounds.

Double-displacement reactions

In a **double-displacement reaction**, ions from two compounds in a solution exchange places to produce two new compounds. One of the compounds formed is usually a precipitate that settles out of the solution, a gas that bubbles out of the solution, or a molecular compound such as water. The other compound formed often remains dissolved in the solution. Precipitates are first recognizable by the cloudy appearance they give to a solution. A precipitate is the result of one of the products in a double-displacement reaction being insoluble in water (Figure 14.14). The term *insoluble* means that it does not dissolve. Depending on the compound formed, the precipitate can be many different colors from white to fluorescent yellow, as in the reaction between lead (II) nitrate and potassium iodide.

$$Pb(NO_3)_{2(aq)} + 2KI_{(aq)} \longrightarrow PbI_{2(s)} + 2KNO_{3(aq)}$$

The general formula for a double-displacement reaction is give below. Each pairing of letters—AB and CD, and AD and CB—are ionic compounds in a solution.

$$AB + CD \longrightarrow AD + CB$$

VOCABULARY

single-displacement reaction - a chemical reaction in which one element replaces a similar element in a compound.

double-displacement reaction - a chemical reaction in which ions from two compounds in solution exchange places to produce two new compounds.

Figure 14.14: *The formation of a cloudy precipitate is evidence that a double-displacement reaction has occurred. If left undisturbed in a beaker, a precipitate will settle to the bottom. The precipitate in the image is potassium iodide.*

Combustion reactions

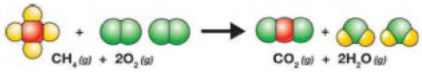
In a combustion reaction, energy is released

A **combustion reaction**, also called burning, occurs when a substance, such as wood, natural gas, or propane combines with oxygen and releases a large amount of energy in the form of light and heat. The products of this kind of combustion reaction are carbon dioxide and water. What do reactants such as wood, natural gas, and propane have in common? The answer is that they are all carbon compounds. Following is the general equation for a combustion reaction.

$$\text{Carbon Compound} + O_{2\,(g)} \longrightarrow CO_{2\,(g)} + H_2O_{(g)}$$

Carbon compounds

The methane reaction, which you have seen before, is a good example of a combustion reaction. As you can see, a carbon compound is a mixture of carbon and hydrogen atoms. The general formula for a carbon compound is C_xH_y where x and y represent different subscripts. Examples of carbon compounds can be found in Figure 14.15.



Another kind of combustion reaction

Not all combustion reactions use carbon compounds as a reactant. These types of combustion reactions do not produce carbon dioxide. For example, when hydrogen gas is burned in oxygen, water is the only product.

$$2H_{2\,(g)} + O_{2\,(g)} \longrightarrow 2H_2O_{(l)}$$

The value of an alternative combustion reaction

Perhaps in the future some of our cars will run by the reaction above. Instead of using gasoline, which is a mixture of carbon compounds, cars might run on hydrogen. Currently, automobile manufacturers are developing technologies that utilize hydrogen combustion in the internal combustion engines of cars. Another way hydrogen can be used to power cars is in an electrochemical process that uses a fuel cell. In either case, the use of hydrogen fuel could help reduce the amount of carbon dioxide emissions related to transportation. However, it would still take energy, sometimes in the form of fossil fuels, to make the hydrogen fuel. What do you think? Should hydrogen technologies be developed for cars?

VOCABULARY

combustion reaction - a chemical reaction that results in a large amount of energy being released when a carbon compound combines with oxygen.

Carbon Compound	Chemical Formula
methane	CH_4
ethane	C_2H_6
propane	C_3H_8
butane	C_4H_{10}
pentane	C_5H_{12}
hexane	C_6H_{14}
heptane	C_7H_{16}
octane	C_8H_{18}

Figure 14.15: *Examples of carbon compounds.*

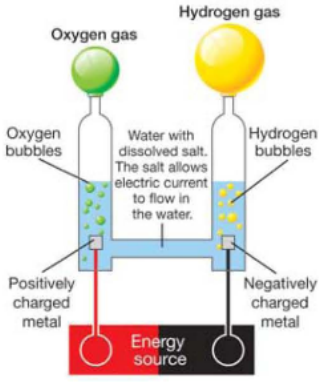
CHALLENGE

Hydrogen Technology

In the text, you learned about two forms of hydrogen technology used for running an automobile. Find out more about each one. Is hydrogen fuel a viable alternative to fossil fuels?

Section 14.2 Review

1. Why is polymerization a type of synthesis reaction?
2. You have learned about the different kinds of chemical reactions. Come up with a set of simple rules that you can use to help you identify each kind of chemical reaction. There are no right or wrong answers. Write rules that make sense to you.
3. The graphic at the right shows the electrolysis of water.
   a. Come up with an explanation for why oxygen forms near the positively charged metal and hydrogen forms near the negatively charged metal.
   b. Why is a greater amount of hydrogen gas collected in this reaction?
   c. Is this reaction occurring in a closed container? Justify your answer.



4. How does the involvement of energy in a decomposition reaction compare to how energy is involved in a combustion reaction?
5. Compare and contrast single-displacement and double-displacement reactions.
6. Identify the following reactions as synthesis, decomposition, single or double displacement, or combustion.
   a. $N_2\,(g) + 3H_2\,(g) \rightarrow 2NH_3\,(g)$
   b. $NH_4NO_3\,(s) \rightarrow N_2O\,(g) + 2H_2O\,(g)$
   c. $AgNO_3\,(aq) + NaCl\,(aq) \rightarrow AgCl\,(s) + NaNO_3\,(aq)$
   d. $Fe\,(s) + H_2SO_4\,(aq) \rightarrow H_2\,(g) + FeSO_4\,(aq)$

BIOGRAPHY

George Washington Carver

George Washington Carver was born around 1864 in Missouri toward the end of the Civil War. George and his mother, a slave for Moses and Susan Carver, were kidnapped when he was an infant. Only George was found and returned to the Carvers who then raised him. Due to frail health, he spent a lot of time exploring nature and developed his talent for studying plants. He pursued plant studies in school and earned an agricultural degree from Iowa State College. He became the first African-American faculty member at the college and earned his master's degree two years later. Soon afterward, Booker T. Washington, founder of Tuskegee Institute in Alabama, recruited Carver to lead the agricultural department. There, Carver taught students and local farmers to rotate crops annually to enrich the soil. Benefits included improving the cotton crop and adding new cash crops such as peanuts and sweet potatoes. Carver is especially known for compiling a list of products and recipes that utilized the peanut plant. His many achievements include conducting research on soy as a possible biofuel, displaying artwork at the 1893 World's Fair, and meeting with three American presidents.