Types of Chemical Reactions

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CONCEPT 1

Types of Chemical Reactions

Lesson Objectives

- Explain how synthesis reactions occur.
- Describe how decomposition reactions occur.
- Describe single and double replacement reactions.
- Explain how combustion reactions occur.

Lesson Vocabulary

- combustion reaction
- decomposition reaction
- replacement reaction
- synthesis reaction

Introduction

Most of the chemical reactions you have seen so far in this chapter are synthesis reactions. In this type of reaction, two or more reactants combine to synthesize a product. There are several other types of chemical reactions, including decomposition, replacement, and combustion reactions. You will read about all four types of reactions in this lesson. **Table** 1.1 summarizes the four types of chemical reactions you will read about in the rest of the lesson. You can see demonstrations of each type at this URL: http://www.youtube.com/watch?v=nVysOW0Lb8U&feature=related.

TABLE 1.1: Four Types of Chemical Reactions

Type of Reaction	General Equation	Example
Synthesis	$A + B \rightarrow C$	$2Na + Cl_2 \rightarrow 2NaCl$
Decomposition	$AB \rightarrow A + B$	$2H_2O \rightarrow 2H_2 + O_2$
Replacement	$A + BC \rightarrow B + AC$	$2K + 2H_2O \rightarrow 2KOH + H_2$
Single Double	$AB + CD \rightarrow AD + CB$	$NaCl + AgF \rightarrow NaF + AgCl$
Combustion	fuel + oxygen $\rightarrow$ carbon dioxide + water	$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

Synthesis Reactions

A **synthesis reaction** occurs when two or more reactants combine to form a single product. A synthesis reaction can be represented by the general equation:

$$A + B \rightarrow C$$

In this general equation (and others like it in this lesson), the letters A, B, C, and so on represent atoms or ions of elements. The arrow shows the direction of the reaction. The letters on the left side of the arrow are the reactants that begin the chemical reaction. The letters on the right side of the arrow are the product of the reaction. Two examples of synthesis reactions are described below. You can see more examples at this URL: http://www.youtube.com/watch?v=dxlWtsFinTM.

Synthesis Example 1

An example of a synthesis reaction is the combination of sodium (Na) and chlorine (Cl) to produce sodium chloride (NaCl). This reaction is represented by the chemical equation:

$$2\text{Na} + \text{Cl}_2 \rightarrow 2\text{NaCl}$$

Sodium is a highly reactive metal, and chlorine is a poisonous gas (see **Figure** 1.1). The compound they synthesize has very different properties. It is table salt, which is neither reactive nor poisonous. In fact, salt is a necessary component of the human diet.

FIGURE 1.1

Sodium and chlorine combine to synthesize table salt.

Synthesis Example 2

Another example of a synthesis reaction is illustrated in **Figure** 1.2. The brown haze in the air over the city of Los Angeles is smog. A major component of smog is nitrogen dioxide (NO_2). It forms when nitric oxide (NO), from sources such as car exhaust, combines with oxygen (O_2) in the air. The equation for this reaction is:

$$2NO + O_2 \rightarrow 2NO_2$$

Nitrogen dioxide is a toxic gas with a sharp odor. It can irritate the eyes and throat and trigger asthma attacks. It is a major air pollutant.

FIGURE 1.2

In this photo, the air over Los Angeles, California is brown with smog.

Decomposition Reactions

A decomposition reaction is the reverse of a synthesis reaction. In a **decomposition reaction**, one reactant breaks down into two or more products. This can be represented by the general equation:

$$AB \rightarrow A + B$$

Two examples of decomposition reactions are described below. You can see other examples at this URL: http://www.youtube.com/watch?v=dxlWtsFinTM.

Decomposition Example 1

An example of a decomposition reaction is the breakdown of carbonic acid (H_2CO_3) to produce water (H_2O) and carbon dioxide (CO_2). The equation for this reaction is:

$$H_2CO_3 \rightarrow H_2O + CO_2$$

Carbonic acid is synthesized in the reverse reaction. It forms when carbon dioxide dissolves in water. For example, some of the carbon dioxide in the atmosphere dissolves in the ocean and forms carbonic acid. The amount of carbon dioxide in the atmosphere has increased over recent decades (see **Figure** 1.3). As a result, the acidity of ocean water is also increasing. How do you think this might affect ocean life?

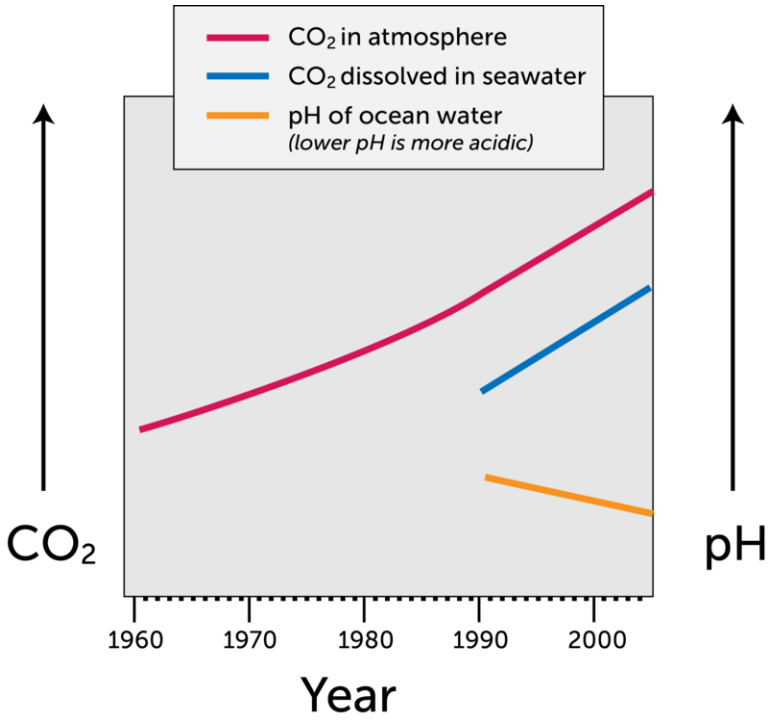

FIGURE 1.3

As carbon dioxide increases in the atmosphere, more carbon dioxide dissolves in ocean water.

Decomposition Example 2

Another example of a decomposition reaction is illustrated in **Figure** 1.4. Water (H_2O) decomposes to hydrogen (H_2) and oxygen (O_2) when an electric current passes through it. This reaction is represented by the equation:

$$2H_2O \rightarrow 2H_2 + O_2$$

What is the reverse of this decomposition reaction? (*Hint*: How is water synthesized? You can look at this chapter's "Introduction to Chemical Reactions" lesson to find out.)

Replacement Reactions

Replacement reactions involve ions. They occur when ions switch places in compounds. There are two types of replacement reactions: single and double. Both types are described below.

Single Replacement Reactions

A single replacement reaction occurs when one ion takes the place of another in a single compound. This type of reaction has the general equation:

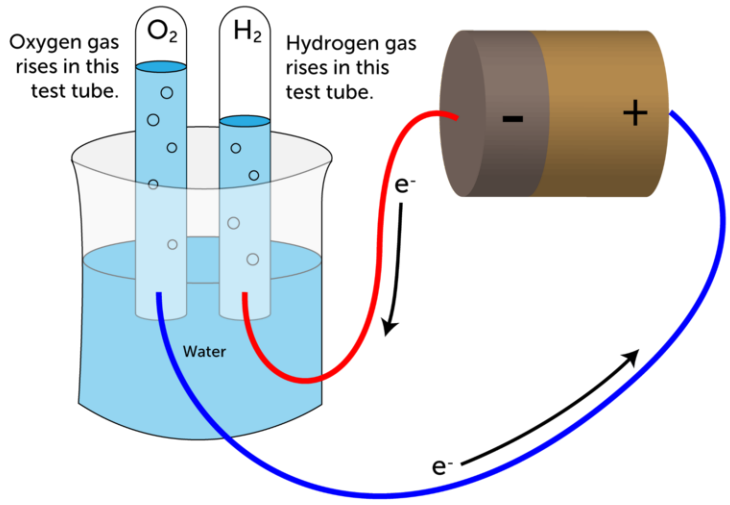

FIGURE 1.4

A decomposition reaction occurs when an electric current passes through water.

$$A + BC \rightarrow B + AC$$

Do you see how *A* has replaced *B* in the compound? The compound *BC* has become the compound *AC*.

An example of a single replacement reaction occurs when potassium (K) reacts with water (H_2O). A colorless solid called potassium hydroxide (KOH) forms, and hydrogen gas (H_2) is released. The equation for the reaction is:

$$2K + 2H_2O \rightarrow 2KOH + H_2$$

Potassium is a highly reactive group 1 alkali metal, so its reaction with water is explosive. You can actually watch this reaction occurring at: http://commons.wikimedia.org/wiki/File:Potassium_water_20.theora.ogv.

Double Replacement Reactions

A double replacement reaction occurs when two compounds exchange ions. This produces two new compounds. A double replacement reaction can be represented by the general equation:

$$AB + CD \rightarrow AD + CB$$

Do you see how *B* and *D* have changed places? Both reactant compounds have changed.

An example of a double replacement reaction is sodium chloride (NaCl) reacting with silver fluoride (AgF). This reaction is represented by the equation:

$$NaCl + AgF \rightarrow NaF + AgCl$$

Cl and F have changed places. Can you name the products of this reaction?

Combustion Reactions

A **combustion reaction** occurs when a substance reacts quickly with oxygen (O_2). You can see an example of a combustion reaction in **Figure** 1.5. Combustion is commonly called burning. The substance that burns is usually referred to as fuel. The products of a combustion reaction include carbon dioxide (CO_2) and water (H_2O). The reaction typically gives off heat and light as well. The general equation for a combustion reaction can be represented by:

$$\text{Fuel} + O_2 \rightarrow CO_2 + H_2O$$

FIGURE 1.5

The burning of charcoal is an example of a combustion reaction.

Combustion Example 1

The fuel that burns in a combustion reaction is often a substance called a hydrocarbon. A hydrocarbon is a compound that contains only carbon (C) and hydrogen (H). Fossil fuels, such as natural gas, consist of hydrocarbons. Natural gas is a fuel that is commonly used in home furnaces and gas stoves (see **Figure** 1.6). The main component of natural gas is the hydrocarbon called methane (CH_4). The combustion of methane is represented by the equation:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

Combustion Example 2

Your own body cells burn fuel in combustion reactions. The fuel is glucose ($C_6H_{12}O_6$), a simple sugar. The process in which combustion of glucose occurs in body cells is called cellular respiration. This combustion reaction provides energy for life processes. Cellular respiration can be summed up by the equation:

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

FIGURE 1.6
The blue flame on this gas stove is produced when natural gas burns.

Where does glucose come from? It is produced by plants during photosynthesis. In this process, carbon dioxide and water combine to form glucose. Which type of chemical reaction is photosynthesis?

Lesson Summary

- A synthesis reaction occurs when two or more reactants combine to form a single product.
- In a decomposition reaction, one reactant breaks down into two or more products. This is the reverse of a synthesis reaction.
- Replacement reactions occur when elements switch places in compounds. In a single replacement reaction, one element takes the place of another in a single compound. In a double replacement reaction, two compounds exchange elements.
- A combustion reaction occurs when a substance reacts quickly with oxygen. Combustion is commonly called burning. Carbon dioxide, water, and heat and light are products of combustion.

Lesson Review Questions

Recall

1. Write an equation for the chemical reaction in which hydrogen reacts with oxygen to form water. What type of reaction is this?
2. Write an equation for the reverse of the reaction in question 1. What type of reaction is this?
3. Name the type of reaction represented by this general equation: $AB + CD \rightarrow AD + CB$
4. In the general equation in question 3, what do the individual letters represent?
5. What are the reactants and products in a combustion reaction?

Apply Concepts

6. Apply lesson concepts to classify the following chemical reactions:

a. $Zn + 2HCl \rightarrow H_2 + ZnCl_2$
b. $2KClO_3 \rightarrow 2KCl + 3O_2$
c. $2KI + Cl_2 \rightarrow 2KCl + I_2$
d. $AgNO_3 + KCl \rightarrow AgCl + KNO_3$

Think Critically

7. Compare and contrast the four types of reactions described in this lesson. Include an example of each type of reaction.

Points to Consider

Combustion reactions release energy. Some other types of reactions absorb energy. They need a continuous supply of energy to occur.

- Can you think of any chemical changes that might absorb energy?
- What might be different about reactions that need energy to keep going?

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