

UNIT 1

CHEMICAL REACTIONS AND STOICHIOMETRY

1.1 Introduction

At the end of this section, students will be able to

- ☞ define chemical reaction;
- ☞ give some examples of chemical reactions.
- ☞ explain physical and chemical changes using examples

Change is the law of nature. We observe various types of changes around us. The growth of seed into a plant, the burning of wood in a fire place, the rusting of iron articles in moist air, the rotting of food and the evaporation of liquids are some of the changes that we see taking place around us. Scientists categorize changes as physical and chemical changes. A physical change is a change that does not involve

the formation of a new substance with a new chemical composition. Examples of physical changes are evaporation of liquids, powdering of sugar and melting of ice. The change which results in the formation of one or more new substances with new chemical composition is known as a chemical change. Examples of chemical changes are turning of milk into curd, photosynthesis by green plants and rotting of egg by bacteria. Chemical changes occur due to chemical reactions between substances. In general, a change is called a chemical reaction if it exhibits all or part of the following characteristics.

- i. Formation of new substances
- ii. Production of heat or light or both
- iii. Change in color
- iv. Change in temperature and etc.

Chemical reaction is the process in which reacting substances, called reactants, are converted into new substances, called **products**. The characteristics of the products are completely different from those of the reactants.

For example, if you burn sulphur with oxygen, the sulphur and oxygen are completely converted to sulphur dioxide. Sulphur dioxide is a colourless gas with a pungent odour. These characteristics of sulphur dioxide are completely different from the characteristics of the original substances, sulphur and oxygen. A **chemical reaction** is represented by a short hand notation called **chemical equation** as:



A chemical equation uses chemical symbols to show what happens during a chemical reaction. A balanced chemical equation can be used to describe the relationships between the amounts of reactants and products. The quantitative study of reactants and products in a chemical reaction is called **reaction's stoichiometry**. In this unit you will study, the types of chemical reactions, chemical equations, redox reactions, chemical formulas, masses of compounds, mole concepts, and reaction's stoichiometry.



Exercise 1.1

- What is a chemical reaction?
- Explain the meanings of chemical and physical changes using examples.
- Give two examples of evidences for chemical reactions not mentioned in the text.

1.2 Chemical Equations

At the end of this section, students will be able to

- ☞ explain the conventions used to write chemical equation;
- ☞ write the chemical equations of varieties of chemical reactions;

- ☞ balance chemical equations using;
 - The Inspection method,
 - The Least Common Multiple (LCM) method,
 - The Algebraic method.



Form a group and discuss each of the following and present your conclusion to the rest of the class.

1. How can you show chemical symbols, physical states and quantities of substances involved in a chemical reaction?
2. What is the difference between a chemical equation and a chemical reaction?
3. Which law is applied when a chemical equation is balanced?

A **chemical equation** is a shorthand representation of an actual chemical reaction in terms of chemical symbols and formulas. In a chemical equation the starting substances are called **reactants**; and the new substances produced are known as **products**.

In a chemical equation, reactants are written on the left side and products on the right side of the equation. An arrow ($\rightarrow$) is placed between the two sides to indicate transformation of reactants into products.



1.2.1 Writing Chemical Equation

In writing chemical equation, instead of using words, chemical symbols and formulas are used to represent the reaction.

Steps to write a chemical equation

1. Write a word equation: A word equation is stated in words. For example, the word equation for the reaction between hydrogen and nitrogen to produce ammonia is written as:

Hydrogen + Nitrogen $\rightarrow$ Ammonia (Word equation)

Note that we read the '+' sign as 'reacts with' and the arrow can be read as 'to produce', 'to form', 'to give' or 'to yield'.

2. Write the symbols and formulas for the reactants and products in the word

$3\text{H}_2 + \text{N}_2 \rightarrow 2\text{NH}_3$ (Balanced equation)

Chemically reactive substances might be solids, liquids, gases, or they can dissolve in a solvent. Particularly ionic compounds commonly react in aqueous solution, or dissolve in water. Sometimes this information is added to an equation by placing the appropriate symbols after the formulas:

(s) - Solid (l) - Liquid (g) - Gas (aq) - Aqueous solution

Example 1.1: Write the chemical equation for the reaction that occurs between calcium carbonate and sulfuric acid.

1. Word equation:

Calcium carbonate + Sulphuric acid $\rightarrow$ Calcium sulphate + Water + Carbon dioxide

2. Chemical equation: $\text{CaCO}_3(\text{s}) + \text{H}_2\text{SO}_4(\text{l}) \rightarrow \text{CaSO}_4(\text{s}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$

3. The equation is balanced

Example 1.2: Write the chemical equation for the reaction of sodium chloride and silver nitrate.

1. Word equation:

Silver nitrate + Sodium chloride $\rightarrow$ Silver chloride + Sodium nitrate

2. Chemical equation: $\text{AgNO}_3(\text{aq}) + \text{NaCl}(\text{aq}) \rightarrow \text{AgCl}(\text{s}) + \text{NaNO}_3(\text{aq})$

3. The equation is balanced.

Generally, any chemical equation must fulfill the following conditions:

- A. An equation must represent a true and possible chemical reaction.
- B. The symbols and formulas must be written correctly. The elements – hydrogen, nitrogen, oxygen, fluorine, chlorine, bromine and iodine exist as diatomic molecules. For example, these elements should be written as molecules in the equation. The equation must be balanced.

A chemical equation has both qualitative and quantitative meanings. **Qualitatively**, a chemical equation indicates the types of the reactants and products in the reaction.

Quantitatively, a chemical equation expresses the relative number (amount) of moles, molecules or masses of the reactants and products. For example, the balanced chemical equation : $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$ has both qualitative and quantitative meaning. Qualitatively, it shows that the reaction between hydrogen and oxygen forms water. Quantitatively, it indicates that two units of hydrogen combine with one unit of oxygen to form two units of water. The quantities may be expressed in terms of grams, number of moles or number of molecules (see for more details in subsection 1.6.1).

Part I: Choose the correct answer for the given questions below

1. According to the text, which of the following best describes a physical change?
 - A. A change that always produces heat or light.
 - B. A change that involves a chemical reaction between substances.
 - C. A change that does not involve the formation of a new substance.
 - D. A change that results in new chemical compositions.
2. Which of the following is provided as an example of a physical change?
 - A. Powdering of sugar.
 - B. Turning of milk into curd.
 - C. Rotting of an egg by bacteria.
 - D. Photosynthesis by green plants.
3. Based on the text, which process is categorized as a chemical change?
 - A. Rotting of food.
 - B. Powdering of sugar.
 - C. Melting of ice.
 - D. Evaporation of liquids.
4. Which of the following is NOT listed as a typical characteristic of a chemical reaction?
 - A. Change in color.
 - B. Production of heat or light
 - C. Change in physical state without new substance formation.
 - D. Formation of new substances.
5. In a chemical reaction, the starting substances are called _____, and the new substances are called _____.
 - A. reactants, products
 - B. elements, compounds
 - C. products, reactants
 - D. solutes, solvents
6. When sulphur burns with oxygen, what new substance is formed according to the provided example?
 - A. Sulphuric acid
 - B. Sulphur trioxide
 - C. Hydrogen sulphide
 - D. Sulphur dioxide
7. What is a chemical equation?
 - A. A shorthand representation of a chemical reaction using symbols.
 - B. A physical tool used to measure the mass of reactants.
 - C. A set of mathematical rules for calculating reaction temperatures.
 - D. A long written description of how a chemical reaction takes place.
8. The quantitative study of reactants and products in a chemical reaction is called:
 - A. Reaction's stoichiometry
 - B. Binomial nomenclature
 - C. Physical transformation
 - D. Reaction's qualitative analysis

9. In a chemical equation, what does the arrow ($\rightarrow$) placed between the two sides indicate?
- A. Heat must be added for the reaction to occur.
 - B. The transformation of reactants into products.
 - C. The reactants are equal in mass to the products.
 - D. The reaction is reversible and can go backward.
10. How is the + sign read in a word equation like 'Hydrogen + Nitrogen $\rightarrow$ Ammonia'?
- A. Produces
 - B. Reacts with
 - C. Yields
 - D. Added to mathematically
11. What does the symbol (aq) placed after a chemical formula indicate?
- A. Active liquid
 - B. Amorphous solid
 - C. Aqueous solution
 - D. Atmospheric gas
12. Which of the following elements does NOT exist as a diatomic molecule in a chemical equation according to the text?
- A. Carbon
 - B. Chlorine
 - C. Oxygen
 - D. Hydrogen
13. In the reaction between calcium carbonate and sulfuric acid (Example 1.1), what gas is produced?
- A. Oxygen
 - B. Carbon dioxide
 - C. Hydrogen
 - D. Nitrogen
14. What does a chemical equation indicate qualitatively?
- A. The types of the reactants and products in the reaction.
 - B. The relative number of moles of the reactants.
 - C. The specific temperature required for the reaction.
 - D. The exact masses of the substances involved.
15. Which aspect of the equation $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$ demonstrates its quantitative meaning?
- A. Two units of hydrogen combine with one unit of oxygen to form two units of water.
 - B. Hydrogen and oxygen are gases while water is a liquid.
 - C. Hydrogen reacts with oxygen to form water.
 - D. The reaction produces a significant amount of heat.

Part II: Answer the following questions as true or false

1. Change is described as the law of nature in the introductory text.
2. The evaporation of liquids is classified as a chemical change.
3. Chemical changes occur due to chemical reactions between substances.
4. The characteristics of the products in a chemical reaction are completely different from those of the reactants.
5. Sulphur dioxide is described as a colorful gas with a sweet odor.
6. In a chemical equation, reactants are written on the right side and products on the left side.
7. The first step in writing a chemical equation is usually writing a word equation.
8. The symbol (l) in a chemical equation stands for a substance dissolved in a solvent.
9. The reaction between silver nitrate and sodium chloride produces solid silver chloride.
10. Fluorine and bromine are examples of elements that exist as diatomic molecules.
11. A chemical equation does not need to represent a true and possible chemical reaction as long as it is mathematically balanced.
12. A chemical equation has both qualitative and quantitative meanings.

Part III: Matching : Match the correct choice for the given questions below and write the correct letter in the space provided

1. Physical Change.....
 - A. Turning milk into curd
 - B. Rotting of food
 - C. Melting of ice
 - D. Burning of wood
2. Chemical Change.....
 - A. Powdering of sugar
 - B. Evaporation of liquids
 - C. Photosynthesis by green plants
 - D. Melting of ice

3. Match the chemical symbol with its correct state of matter: (s).....
 - A. Sublimation
 - B. Solvent
 - C. Solution
 - D. Solid**
4. Match the chemical symbol with its correct state of matter: (g).....
 - A. Gallon
 - B. Grams
 - C. Ground state
 - D. Gas**
5. Match the term with its correct definition: Reactants.....
 - A. The quantitative study of a chemical reaction.
 - B. The starting substances in a chemical equation.**
 - C. The shorthand notation of a chemical reaction.
 - D. The new substances produced in a chemical equation.
6. Match the term with its correct definition: Products.....
 - A. The starting substances in a chemical equation.
 - B. The new substances produced in a chemical equation.**
 - C. The elements that exist as diatomic molecules.
 - D. The physical states of matter in a reaction.
7. Match the concept with its correct description: Qualitative meaning.....
 - A. Expresses the relative number of moles of the reactants and products.
 - B. Identifies the physical state symbols used in the equation.
 - C. Shows the exact mathematical balance of the chemical equation.
 - D. Indicates the types** of the reactants and products in the reaction.
8. Match the concept with its correct description: Quantitative meaning.....
 - A. Indicates the specific types of the reactants and products.
 - B. Describes the physical properties of the starting materials.
 - C. Expresses the relative number** of moles or molecules of substances.
 - D. Identifies the color changes that occur during a reaction.
9. Match the given chemical equation to its specific type: 'Hydrogen + Nitrogen $\rightarrow$ Ammonia'.....
 - A. Quantitative equation
 - B. Balanced chemical equation

- C. Word equation
D. Unbalanced symbolic equation
10. Match the given chemical equation to its specific type based on the text: $\text{H}_2 + \text{N}_2 \rightarrow \text{NH}_3$
- A. Qualitative equation
B. Word equation
C. Balanced equation
D. Unbalanced equation
11. Match the following element to its correct classification as a diatomic molecule as listed in the text.....
- A. Chlorine
B. Calcium
C. Copper
D. Carbon
12. Match the condition with the requirement for writing any valid chemical equation.....
- A. It must be written using only word equations.
B. It must only contain substances in the gaseous state.
C. It must represent a true and possible chemical reaction.
D. It must always produce heat or light as a product.