CHAPTER 4
CHEMICAL REACTIONS

A chemical rxn. is a process in which one set of substances, called reactants, is converted to a new set of substances, called products.

$$\overbrace{\underbrace{A + B}_{\text{Reactants}} \longrightarrow \underbrace{C}_{\text{Product}}}^{\text{Chemical rxn.}}$$

→ Evidences that showing the occurance of a reaction

- Color change
- Formation of a solid within a clear solution
- Evolution of a gas
- Evolution or absorption of heat.

Although such observations are significant to show that a rxn. has occured, a detailed ~~analysis~~ chemical analysis is required to obtain a conclusive evidence.

→ Chemical equations are used to represent chemical rxn.s

How do we write chemical equations?

Example

$$NO + O_2 \longrightarrow NO_2$$

formulas of reactants on the left hand side

The two sides of the equation are joined by an arrow.

products are on the right

Since atoms are neither created nor destroyed in any kind of rxn., a chemical equation must have an equinumber of atoms on each side of the arrow.

Whe a reaction meets this condition, it is said to be balanced.

$$2NO + O_2 \longrightarrow 2NO_2$$

* The coefficients balancing a chemical equation are called as stoichiometric coefficients.

Guidelines to Balance a Chemical Equation

① An equation can be balanced only by adjusting the coefficients of formulas.

② The equation must include only the reactants and products

$$NO + O_2 \longrightarrow NO_2 + \cancel{O} \quad \text{(incorrect)}$$

③ Never balance an equation by changing a formula.

$$NO + O_2 \longrightarrow NO_3 \quad \text{(incorrect)}$$

→ Some useful strategies for balancing equations

a) If an element occurs in only ~~one side of a~~ one compound on each side of the equaition, try balancing this element first.

$$H_3PO_4 + \underset{\uparrow}{CaO} \longrightarrow \underset{\uparrow}{Ca_3}(PO_4)_2 + H_2O$$

b) When one of the reactants or products exists as a free element balance this element last.

$$NH_3 + \underset{\uparrow}{O_2} \longrightarrow NO_2 + H_2O$$

c) Im some rxn.s, certain groups of atoms remain unchanged. (for exampe, polyatomic ions). In such cases balance this groups as a unit.

$$PO_4^{3-}, \quad NO_3^-, \quad SO_4^{2-}, \quad CO_3^{2-}$$

d) Coefficients can be integral or fractional numbers.

2, 3, 3/2, 1/2

Example:

$$NH_3 + O_2 \longrightarrow N_2 + H_2O$$

$$2NH_3 + O_2 \longrightarrow N_2 + H_2O$$

$$2NH_3 + O_2 \longrightarrow N_2 + 3H_2O$$

$$2NH_3 + \tfrac{3}{2}O_2 \longrightarrow N_2 + 3H_2O \quad \text{(balanced)}$$

× 2

$$4NH_3 + 3O_2 \longrightarrow 2N_2 + 6H_2O \quad \text{(balanced)}$$

Example: Balance the chemical equation of the reaction of triethylene glycol an O_2.

$$C_6H_{14}O_4 + O_2 \longrightarrow CO_2 + H_2O$$

C →

$$C_6H_{14}O_4 + O_2 \longrightarrow 6CO_2 + H_2O$$

H →

$$C_6H_{14}O_4 + O_2 \longrightarrow 6CO_2 + 7H_2O$$

O →

4 Oxygen   12 Ox.   7 Ox.

$$C_6H_{14}O_4 + \tfrac{15}{2}O_2 \longrightarrow 6CO_2 + 7H_2O \quad \text{(balanced)}$$

× 2

$$2C_6H_{14}O_4 + 15O_2 \longrightarrow 12CO_2 + 14H_2O \quad \text{(balanced)}$$

States of Matter in Chemical Equations

Following symbols are used to show the physical form of reactants and products.

(g) : Gas , (l) : liquid , (s) : solid

(aq.) : aqueous (dissolved in water)

→ $$2C_6H_{14}O_4\,(l) + 15O_2\,(g) \rightarrow 12\,CO_2\,(g) + 14\,H_2O\,(l)$$

Reaction Conditions

The rxn. conditions are often written above or below the arrow in an equitation.

$$2\,Ag_2O\,(s) \xrightarrow{\Delta} 4\,Ag\,(s) + O_2\,(g)$$

$$CO\,(g) + 2H_2\,(g) \xrightarrow[\substack{340\text{ atm}\\ ZnO,\ Cr_2O_3}]{350°C} CH_3OH\,(g)$$

340 atm → pressure

ZnO, Cr_2O_3 → catalyst

Example : what mass of O_2 is consumed in the complete combustion of 6.86 g of triethylene glycol.

$$2C_6H_{14}O_4 + 15O_2 \rightarrow 12CO_2 + 14H_2O$$

$$?\,g\,O_2 = 6.86\,g\,C_6H_{14}O_4 \,\frac{1\text{ mol }C_6H_{14}O_4}{150.2\,g} \times \frac{15\text{ mol }O_2}{2\text{ mol }C_6H_{14}O_4} \times \frac{32\,g\,O_2}{1\text{ mol }O_2}$$

$$= 11\,g\,O_2.$$

Chemical Rxn.s In Solutions :

Most rxn.s are carried out in solution. One component of a solution is called the solvent, indicates whether the solution exists as a solid, liquid or gas.

Molarity: The composition of a solution may be specified by giving its molarity, which is defined as the amount of solute, in moles, per liter of solution.

$$\text{molarity} = \frac{\text{amount of solute (in moles)}}{\text{volume of solution (in liters)}} = \frac{mol}{L}$$

$$M = \frac{n}{V}$$

Example: A solution is prepared by dissolving 25.0 mL ethanol (CH_3CH_2OH) in enough water to produce a 250.0 mL solution. What is the molarity of ethanol? ($d_{ethanol} = 0.789\ g/mL$)

$$M = \frac{n}{V} \rightarrow \text{find } n \text{ of ethanol}$$

$$?\ \text{mol ethanol} = 25.0\ \text{mL ethanol} \times \frac{0.789\ \text{g/mL eth.}}{1\ \text{mL eth.}} \times \frac{1\ \text{mol eth.}}{46.07\text{g eth.}}$$

$$= 0.428\ \text{mol } CH_3CH_2OH$$

$$M = \frac{0.428\ \text{mol ethanol}}{0.2500\ \text{L solvent}} = 1.71\ M\ CH_3CH_2OH$$

Example: What mass of K_2CrO_4 is needed to prepare 250 mL of a 0.250 M K_2CrO_4 solution in water.

$$?\ g\ K_2CrO_4 = 0.2500\ \text{L soln} \times \frac{0.250\ \text{mol } K_2CrO_4}{1\ \text{L soln}} \times \frac{194.2\ g\ K_2CrO_4}{1\ \text{mol } K_2CrO_4}$$

$$= 12.1\ g\ K_2CrO_4$$

$M = \frac{n}{V} \Rightarrow n = M.V$. $\quad n\ K_2CrO_4 \longrightarrow m\ K_2CrO_4$

$$n = \frac{m}{M_w} \Rightarrow m = n.M_w$$

Solution Dilution

Dilution is used to prepare dilute solutions from so-called stock solutions that stored as highly concentrated solutions.

When a volume of solution is diluted, the amount of solute remains constant. So the mol of solute.

$$n_i = n_f$$

since

$$n_i = M_i \cdot V_i \quad \text{and} \quad n_f = M_f V_f$$

$$\boxed{M_i V_i = M_f V_f}$$

This equation is used to find final conc. of a diluted solution.

Example: What volume of 0.250 M NaOH must be diluted with water to obtain a 0.250 L of 0.0100 M NaOH.

$$M_i V_i = M_f V_f$$

$$0.250 \times V_1 = 0.010 \times 0.250$$

$$V_i = 0.01 \text{ L} = 10 \text{ mL soln}$$

Determining the Limiting Reactant

The reactant that is completely consumed in a rxn. is called as the Limiting Reactant. The limiting reactant determines or limits the amounts of products formed.

Example:

$$P_4(s) + 6Cl_2(g) \longrightarrow 4PCl_3(l)$$

What is the maximum mass of PCl_3 that can be formed from 125g P_4 and 323g Cl_2?

$$? \text{ mol } Cl_2 = 323 \text{ g } Cl_2 \times \frac{1 \text{ mol } Cl_2}{70.91 \text{ g } Cl_2} = 4.56 \text{ mol } Cl_2$$

$$? \ P_4 = 125 \text{ g } P_4 \times \frac{1 \text{ mol } P_4}{123.9 \text{ g } P_4} = 1.01 \text{ mol } P_4$$

$\frac{P_4}{Cl_2} = \frac{1}{6}$ → Since there is less than 6 mol Cl_2 per mole of P_4, Chlorine (Cl_2) is the limiting reactant.

* If more than 6 mol Cl_2 was available per mole of P_4, P_4 would have been the limiting reactant.

$$? \text{ g } PCl_3 = 4.56 \text{ mol } Cl_2 \times \frac{4 \text{ mol } PCl_3}{6 \text{ mol } Cl_2} \times \frac{137.3 \text{ g } PCl_3}{1 \text{ mol } PCl_3}$$

$$= 417 \text{ g } PCl_3$$

What mass of P_4 remains?

$$\text{g } Cl_2 \rightarrow \text{mol } Cl_2 \rightarrow \text{mol } P_4 \rightarrow \text{g } P_4 \quad \text{or}$$

$$? \text{ g } P_4 = 417 \text{ g } PCl_3 \times \frac{1 \text{ mol } PCl_3}{137.3 \text{ g } PCl_3} \times \frac{1 \text{ mol } P_4}{4 \text{ mol } PCl_3} \times \frac{133.9 \text{ g } P_4}{1 \text{ mol } P_4}$$

$$= 94.1 \text{ g } P_4$$

$125 \text{ g } P_4 - 94.1 \text{ g } P_4 = 31 \text{ g } P_4$ remaining.

Theoretical Yield: The theoretical yeild of a rxn., is the calculated quantity of product expected from given quantities of reactants.

$$A + B \rightarrow C \quad (10 \text{ g})$$

Actual Yield: The quantity of product that is actually produced is called the actual yield.

$$A + B \rightarrow C \quad (8.5 \text{ g obtained})$$

Percent Yield:

$$\text{percent yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$$

$$A + B \rightarrow C \qquad py = \frac{8.5}{10} \times 100 = 85\%$$

Factors
→ ~~Reason of the~~ effecting the actual yeild

a) Loss of product during purification
b)