Stoichiometric Calculations

1. In general a reaction between reacting substances is described by balanced chemical equation.

$$aA + bB \rightarrow cC + dD$$

In the above equation, A and B are reactants and C and D are products. A balanced equation is also called stoichiometric equation. The coefficients a, b, c and d are called stoichiometric coefficients of the substances. These coefficients give the idea of the quantities of the substances consumed and also the substances produced in chemical reactions.

2. A balanced equation provides the following information

i) The reactants and products involved in the chemical change.

ii) The relative number of moles or molecules of the reactants and products.

iii) The relative number of parts of mass of reactants and products.

iv) The relative volumes of gaseous reactants and products.

*The quantitative relationship existing between the quantities of the reactants and the products in a chemical reaction is known as stoichiometry.

3. Mole is translated to weight or volume or number of particles, which is helpful in stoichiometric calculations. The important relationships in calculations based on chemical equations are

i) Weight - weight relationships

ii) Weight - volume relationships

iii) Volume - volume relationships.

4. In order to use the above relationships one must recollect the following three concepts.

a. One mole is gram molecular weight of a substance. In case of monoatomic substances and metal vapours mole is taken as gram atomic weight. If the substance is in the form of ions, mole is taken as gram ionic weight.

b. One mole represents a gas, whose volume is called gram molar volume. Gram molar volume of a gas at standard temperature and pressure is 22.4 L or 22,400cc.

c. One mole denotes Avogadro number of elementary chemical units. Avogadro constant is written as 6.023×10^{23}.

5. Limiting factor

The reactant which is present in lesser amount and gets consumed after sometime. No further reaction takes place whatever be the amount of the other reactant present. Hence, the reactant which gets consumed, limits the amount of product formed. Therefore, the reactant that limits the product formation is called limiting regent and the concept is termed as limiting factor.

The limiting factor must also be kept in mind, in performing calculations based on chemical equations.

6. Weight - Weight relationship

It is possible to calculate the amounts of products formed in a chemical reaction, if the amounts of the reactants participating in the reaction are known. This is possible only if the stoichiometric equation is known.

E.g.: What weight of magnesia is obtained by complete combustion of two grams of metal?

Sol: The balanced equation for the combustion of magnesium metal is

$$2Mg + O_2 \rightarrow 2MgO$$

2 moles of Mg → 2 moles of MgO

1 mole of Mg → 1 mole of MgO

24 grams of Mg→ 40 grams of MgO

The weight of magnesia (MgO) produced by burning 2 grams of metal = 40× 2 /24 = 3.333 grams

7. Weight - Volume relationship

This method of calculations based on equations is employed when one or more of the reactants or products of the reaction are present in gaseous state. This method makes use of (a) converting mole to gram molar volume (b) equation of state

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

E.g. Certain mass of potassium chlorate is thermally decomposed and 3.36 L of O_2 is collected at STP. What will be the weight of the residue in the experiment?

Solution: Potassium chlorate on decomposition gives potassium chloride and oxygen

$$2KClO_3 \rightarrow 2KCl + 3O_2$$

3 moles of O_2 →2 moles of KC*l*

(3 × 22.4) L of O_2 at STP = (2 ×74.5) grams of KC*l*

The weight of KCl obtained when 3.36 L of O_2 is collected at STP = (3.36/3X22.4) × 2 × 74.5 = 7.45 grams

8. Volume - Volume relationship

If gases are used as reactants and gases are produced in the reaction, Gay-Lussac's law of combining volumes may be used for calculations based on equations.

The mole coefficients of gaseous substances give the volumes or volume ratio of the substances directly.

E.g. Calculate the volume of O_2 at STP required to burn completely 70mL of acetylene

Sol: Combustion of acetylene is given as

$$2C_2H_2 + 5O_2\ 4CO_2 + 2H_2O$$

2 moles of C_2H_2 Volume - Volume relationship

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Stoichiometric calculations are very simple if law of combining volumes is useful.

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Sol: Combustion of acetylene is given as

$$2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O$$

2 moles of $C_2H_2 \rightarrow$ 5 moles of O_2

2 volumes of C_2H_2 = 5 volumes of O_2

2 ml of C_2H_2 = 5 ml of O_2

Volume of oxygen required to burn 70mL of acetylene = (70/2) ×5 = 175 ml.