STOICHIOMETRY

Stoichiometry and Stoichiometric Calculations

Stoichiometry, as a specialized branch of chemistry, is concerned with the meticulous calculation of diverse quantities pertaining to the reactants and products involved in a chemical reaction. The term "stoichiometry" finds its etymological roots in two Greek words: "stoichion," translating to element, and "metry," which signifies measurement.

In essence, stoichiometry delves into the quantitative aspects of chemical reactions, offering a systematic approach to comprehend and calculate the quantities of substances undergoing transformation. This branch of chemistry plays a pivotal role in unraveling the intricate relationships between reactants and products, shedding light on the fundamental principles governing the composition and measurement of elements in chemical processes.

Stoichiometric calculations, integral to stoichiometry, provide a structured methodology for determining the ratios, amounts, and relationships between different substances involved in a reaction. By employing mathematical precision, stoichiometric calculations enhance our understanding of the quantitative dynamics inherent in chemical transformations. In summary, the combined exploration of stoichiometry and its calculations contributes significantly to the broader comprehension of chemical reactions and their underlying quantitative principles.

Limiting Reagent

The initial reactant consumed in the reaction is the limiting reactant when working with a balanced chemical equation. In a balanced chemical equation, if the number of moles of reactants does not align with the stoichiometric coefficients, one reactant will act as the limiting reactant.

Ex. Three moles of Na_2CO_3 are reacted with 6 moles of HCl solution. Find the volume of CO_2 gas produced at STP. The reaction is

$$Na_2CO_3 + 2\ HCl \longrightarrow 2\ NaCl + CO_2 + H_2O$$

Sol. From the reaction: $Na_2CO_3 + 2\ HCl \longrightarrow 2\ NaCl + CO_2 + H_2O$

gives moles 3 mol 6 mol

given mole ratio 1 : 2

Stoichiometric coefficient ratio 1 : 2

See here given moles of reactant are in stoichiometric coefficient ratio therefore non reactant left over. Now use Mole-mole analysis to calculate volume of CO_2 produced at STP

$$\frac{\text{Moles of } Na_2CO_3}{1} = \frac{\text{Mole of } Co_2 \text{produced}}{1}$$

Moles of CO_2 produced $= 3$

volume of CO_2 produced at STP $= 3 \times 22.4\ L = 67.2\ L$

Ex. 6 moles of Na_2CO_3 are reacted with 4 moles of HCl solution. Find the volume of CO_2 gas produced at STP. The reaction is

$$Na_2CO_3 + 2\ HCl \longrightarrow 2\ NaCl + CO_2 + H_2O$$

Sol. From the reaction: $Na_2CO_3 + 2\ HCl \longrightarrow 2\ NaCl + CO_2 + H_2O$

gives moles of reactant 6 : 4

given molar ratio 3 : 2

Stoichiometric coefficient ratio 1 : 2

Here, the provided number of moles for reactants does not align with the stoichiometric coefficient ratio. Consequently, there will be a reactant that is consumed first and becomes the limiting reagent. However, determining which reactant is limiting is not a challenging task; you can easily ascertain it using the following method.

How To Find Limiting Reagent

Step: I

Divided the given moles of reactant by the respective stoichiometric coefficient of that reactant.

Step: II

See for which reactant this division come out to be minimum. The reactant having minimum value is limiting reagent for you.

Step: III

Now once you find limiting reagent then your focus should be on limiting reagent

From	Step I & II	Na_2CO_3	HCl
		$\frac{6}{1} = 6$	$\frac{4}{2}=2$ (Division in minimum)

$\therefore$ HCl is Limiting Reagent

From Step III

From $\frac{\text{Mole of HCl}}{2} = \frac{\text{Mole of } CO_2 \text{Produced}}{2}$

$\therefore$ mole of CO_2 produced = 2 moles

$\therefore$ volume of CO_2 produced at S.T.P. = 2 × 22.4 = 44.8 L

Ex. Calculate the weight of FeO from 4 g VO and 5.75 g of Fe_2O_3. Also report the limiting reactant.

$$VO + Fe_2O_3 \longrightarrow FeO + V_2O_5$$

Sol. Balanced equation $2VO + 3Fe_2O_3 \longrightarrow 6FeO + V_2O_5$

Moles before reaction $\frac{4}{67} = 0.05970$ $\quad \frac{5.75}{160}$ 0.03590

Moles after reaction (0.05970–0.0359) $(\frac{6}{3}\times 0.0359)$ $(\frac{1}{3}\times 0.0359)$

As 2 moles of VO react with 3 moles of Fe_2O_3

$\therefore$ 0.05970 g moles of VO $= \frac{3}{2} \times 0.05970 = 0.08955$ moles of Fe_2O_3

Moles of Fe_2O_3 available = 0.0359 only

Hence, Fe_2O_3 is the limiting reagent.

Moles of FeO formed $= \frac{6}{3} \times 0.0359$

$\therefore$ Weight of FeO formed = 0.0359 × 2 × 72 = 5.17 g

$$\left(\frac{n_{FeO}}{n_{Fe_2O_3}} = \frac{6}{3}\right)$$

$\Rightarrow$ $n_{FeO} = \frac{6}{3} \times nFe_2O_3$

$W_{FeO} = \frac{6}{3} \times n_{Fe_2O_3} \times M_{Fe_2O_3}$

Ex. The reaction $2C + O_2 \longrightarrow 2CO$ is carried out by taking 24 g of carbon and 128 g of O_2.

Find out:

(i) Which reactant is left in excess?

(ii) How much of it is left?

(iii) How many moles of CO are formed?

(iv) How many grams of other reactant should be taken so that nothing is left at the end of reaction?

Sol.

	$2C$	$+ O_2$	$\longrightarrow 2CO$
Mole before reaction	$\frac{24}{12}$	$\frac{128}{32}$	
Mole after reaction	0	3	2

∵ Mole ratio of C : O_2 : CO : : 2 : 1 : 2

(i) O_2 is left in excess.

(ii) 3 moles of O_2 or 96 g of O_2 is left.

(iii) 2 moles of CO or 56 g of CO is formed.

(iv) To use O_2 completely, total 8 moles of carbon or 96 g of carbon is needed.

Percentage Yield: The percentage yield of product

$$= \frac{\text{actualyield}}{\text{thetheoretical max imumyi}} \times 100$$