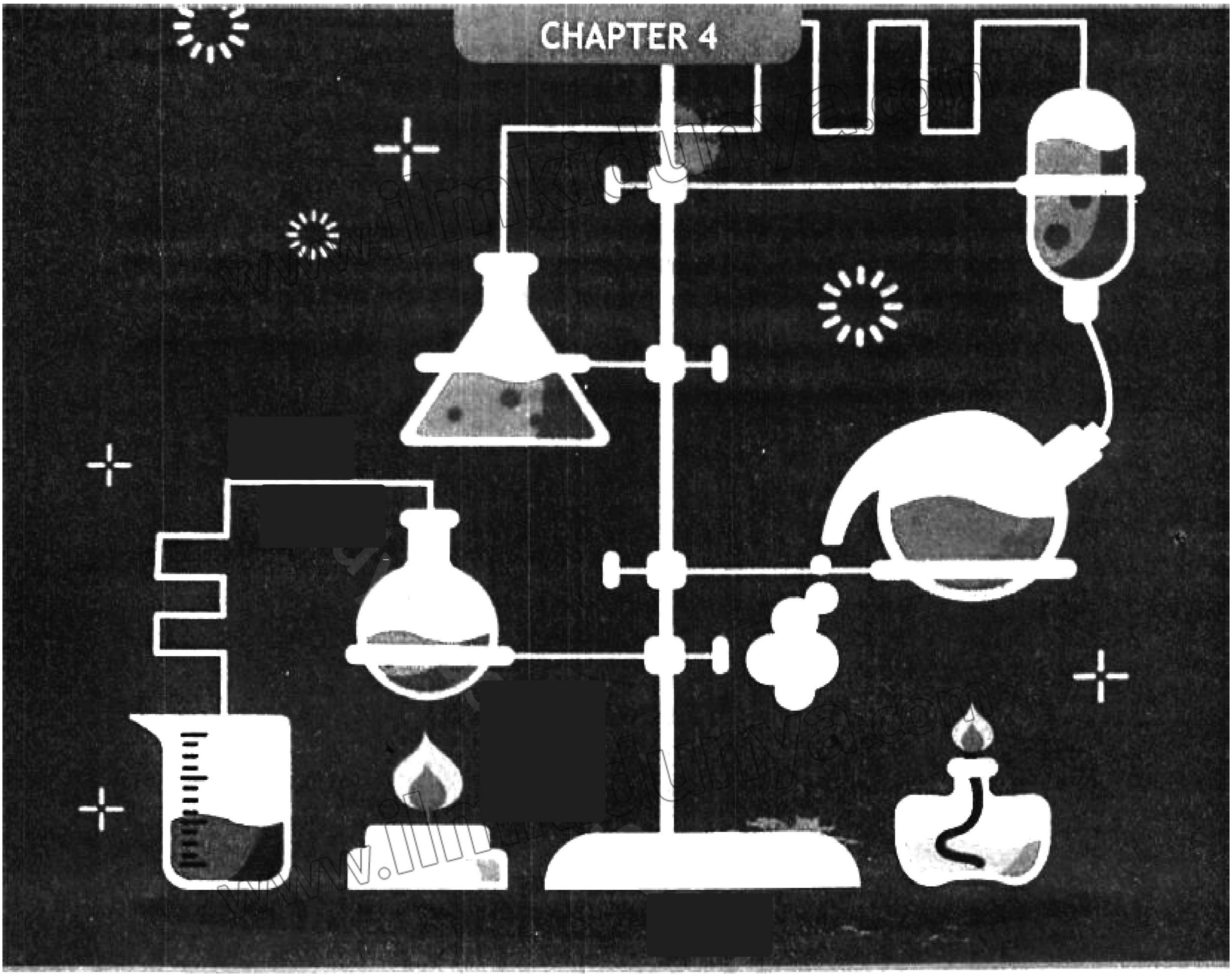

STOICHIOMETRY

SLOs: After completing this lesson, the student will be able to:

1. Express balanced chemical equations in terms of moles, representative particles, masses, and volumes of gases at STP.
2. Explain the concept of limiting reagents.
3. Calculate the maximum amount of product and amount of any unreacted excess reagent.
4. Calculate theoretical yield, actual yield, and percentage yield when given appropriate information.
5. State the volume of one mole of a gas at STP.
6. Use the volume of one mole of gas at STP to solve mole-volume problems.
7. Calculate the gram molecular mass of a gas from density measurements at STP.
8. Derive measurements of mass, volume, and number of particles using moles.
9. Calculate the quantities of reactants and products involved in a chemical reaction using stoichiometric principles. (Some examples include calculations involving reacting masses, volumes of gasses, volumes, and concentrations of solutions, limiting reagent and excess reagent, percentage yield calculations).
10. Explain with examples, the importance of stoichiometry in the production and dosage of midicne.

What does a chemical equation indicate? The elements and compounds react together in definite proportions. The study of the relationships between the amounts of the reactants and the products is referred to as stoichiometry. The word stoichiometry is derived from Greek words, stoicheion means element, and metron, means measurement. Such a study is essential when quantitative information about a chemical reaction is required. Moreover, it is important to predict the yields of products in chemical reactions.

4.1 MOLE

Remember that chemists use the mole as the SI unit to weigh and count atoms, molecules, and ions. A mole is the amount of substance that contains 6.023×10^{23} representative particles. This experimentally determined number is called Avogadro's number. Just as a dozen represents 12 identical things, a mole represents 6.023×10^{23} particles of a substance. For example, a mole of carbon is 6.023×10^{23} carbon atoms. A mole of sodium is 6.023×10^{23} Na atoms. One mole of water is 6.023×10^{23} H_2O molecules. The terms for particles are atoms, molecules or ions. This relationship allows us to convert moles into representative particles and vice versa.

The atomic mass, formula mass and molecular weight of a substance in grams are equal to one mole of the substance. This relationship allows us to convert the mass of a substance to moles and vice versa. For example,

One mole of O atoms = 16 g

One mole of O_2 molecules = 32 g

One mole of H_2O molecules = 18 g

One mole of Na^+ ions = 23 g

One mole of NaCl formula units = 58.5 g

4.1.1 Molar Volume (V_m)

One mole of any gas at STP (standard temperature and pressure) occupies a volume of 22.414 dm^3. This volume is called Molar volume. With the help of this relationship, we can convert the mass of a gas at STP into its volume and vice versa.

22.414 dm^3 of any gas at STP = 1 mole = 6.02×10^{23} molecules.

22.414 dm^3 of H_2 gas at STP = 2g = 6.02×10^{23} molecules.

22.414 dm^3 of NH_3 gas at STP = 17g = 6.02×10^{23} molecules.

Example 4.1:

Determine the volume of 2.5 moles of chlorine molecules at STP.

Solution:

We know that

22.414 dm^3 of Cl_2 at STP = 1 mole

Or 1 mole of Cl_2 occupies a volume of 22.414 dm^3 at STP.

2.5 mole of Cl_2 occupy a volume of $22.414 dm^3 \times 2.5 = 56.035 dm^3$

4.1.2 Molar mass and density of gases

Density is defined as the mass per unit volume of a substance. As molar mass of all the gases occupies same volume at STP. Therefore, density of a gas is depended on its molar mass. A gas having higher molar mass will have higher density and vice versa. So, density of a gas can be calculated from its molar mass and molar volume. If the density of gas at STP is determined, its molar mass can be calculated.

Example 4.2:

Calculate the gram molecular mass of a gas which has density of 1.43 g/dm^3 at STP.

Solution:

1 dm^3 of gas at STP = 1.43g

22.4 dm^3 of gas at STP = 1.43 x 22.4

= 32.032g

As 22.4 dm^3 of a gas at STP = molar mass

Therefore, gram molecular mass of gas is 32.032 amu.

Concept Assessment Exercise 4.1

1. How many moles of oxygen molecule are there in 20.0 dm^3 of oxygen gas at STP?
2. What volume does 0.6 mole of H_2 gas occupy at STP?

4.1.3 Stoichiometric Calculations and Mole Ratio

What does a **balanced chemical equation tell us?**

Consider the following reaction,

$$2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(g)}$$

We get the following information from this chemical equation.

i. 2 moles of H_2 combine with 1 mole of O_2 to produce 2 moles of H_2O

ii. 2 x 6.02 x10^{23}molecules of hydrogen react with 6.02 x 10^{23} molecules of oxygen to produce 2 x 6.02 x 10^{23} molecules of water vapour.

iii. 4g(2 moles) of H_2 combine with 32g(1 mole) of O_2 to produce 36g(2 moles) of H_2O

iv. At STP, 2 ×22.414 dm^3 of H_2 combine with 1 × 22.414 dm^3 of O_2 to produce 2 × 22.414 dm^3 of H_2O vapour.

Example 4.3:

When 100g of magnesium is treated with dilute hydrochloric acid. What volume of hydrogen can be collected at STP?

$$Mg_{(s)} + 2HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$$

Solution:

Moles of Mg = $\frac{100}{24}$ = 4.17

1 mol of Mg produces = 1mol of H_2 at STP

1 mol of Mg produces = 1 x 22.4 dm^3 of H_2 at STP

So, 4.17 mol Mg will produce = 22.4 dm^3 x 4.17 = 93.408 dm^3 of H_2 at STP

Example 4.4:

$$NaCl \xrightarrow{H_2O} Na^{1+}_{(aq)} + Cl^{1-}_{(aq)}$$

i. The chemical equation shows that 1 mole of NaCl when dissolved in water gives 1 mole of Na^{1+} ions and 1 mole of Cl^{-1} ions.

ii. When 6.02×10^{23} formula units of NaCl are dissolved in water, they produce 6.02×10^{23} Na^{1+} and 6.023×10^{23} Cl^{1-} ions.

iii. 58.5g of NaCl dissolved in water gives 23g of Na^{1+} ions and 35.5g of Cl^{1-} ion

Concept Assessment Exercise 4.2

1. What quantative information do you get from the following chemical equation.

$$C_3H_{8(g)} + 5O_{2(g)} \longrightarrow 3CO_{2(g)} + 4H_2O_{(g)}$$

2. Compare and contrast the terms, molecular mass and molar mass
3. What mass of Zn is needed to produce 100 cm^3 of H_2 at STP

$$Zn_{(s)} + HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_{2(g)}$$

Using mole as unit of quantity we can calculate mass, volume, molecules etc. particles used in calculations.

4.1.4 Mole -mole calculation

In a balanced chemical equation, the coefficient used are taken as mole that indicate the proportion to the next chemical in equation e.g.,

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

The reaction indicates that for complete burning of one mole of CH_4 require 2 mole of O_2 or 1 mole of methane can produced 2 moles of water and 1 mole of CO_2.

Example 4.5:

How much MgO formed when 4 moles of magnesium react with excess of O_2. Also calculate moles of O_2 required?

Solution:

$2Mg + O_2 \rightarrow 2MgO$

2 moles of Mg produce MgO = 2 moles

1 moles of Mg produces MgO = 2/2

4 moles of Mg produce MgO =2/2 x4 = 4moles of MgO

So 4 moles of Mg give 4 moles of MgO

Similarly

2 moles of Mg required O_2 = 1 mole

1 moles of Mg required O_2 = 1/2 mole

4 moles of Mg required O_2 =1/2 x4 = 2 moles of O_2

Hence 4 moles of Mg needed 2 mole of O_2

Do You Know?

What is the Mole Day?

The mole day is a sort of funny celebration day for chemists, which takes place on October 23 between 6:02 am and 6:02 pm. This makes the date to be 6:02 10^{23}. This celebrates basically Avogadro constant, which is roughly $6.02 \cdot 10^{23}$.

4.1.5 Mole - mass calculations:

Example 4.6

Potassium chlorate is used in making matches and dyes, on decomposition, it produces KCl and oxygen gas.

If 25 g $KClO_3$ is decomposed, calculate the quantities of the following:

a) How many moles of O_2 are produced.

b) How much mass in gram of O_2 is produced.

Solution:

$2KClO_3 \rightarrow 2KCl + 3O_2$

Given mass of $KClO_3$ = 25g

Molar mass of $KClO_3$ = 39+35.5+16x3=122.5g/mole

Moles of $KClO_3$ = 25/122.5= 0.204 moles

2 moles of $KClO_3$ give oxygen =3 moles

0.204 moles of $KClO_3$ give oxygen =3/2x0.204= 0.306 moles of O_2

b) Mass of O_2 =moles x molar mass

=0.306 x 32 = 9.796 grams

Concept Assessment Exercise 4.3

1. CO can reduce iron (III) oxide into iron metal. How many moles of CO are needed to reduce 5 moles of Fe_2O_3.

$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$$

2. Calculate amount of phosphine (PH_3) that can be prepare when 1 mole of calcium phophide (Ca_3P_2) reacts with excess of H_2O.

$$Ca_3P_2 + 6H_2O \longrightarrow 3Ca(OH)_2 + 2PH_3$$

3. Methanol burns according to the following equation.

$$2CH_3OH_{(l)} + 3O_{2(g)} \longrightarrow 2CO_{2(g)} + 4H_2O_{(g)}$$

If 3.50 moles of methanol are burnt in oxygen, calculate

(a) How many moles of oxygen are used?

(b) How many moles of water are produced?

4. Calculate the no. of molecules and volume of O_2 at STP produced by thermal decomposition of 490 grams of $KClO_3$

Example 4.7

20g of H_2SO_4 on dissolving in water ionizes completely. Calculate

a) No. of H_2SO_4 molecules

b) No. of H^+ and SO_4^{-2}

c) Mass of individual ions

Solution

a. Mass of H_2SO_4 = 20g

Molar Mass of H_2SO_4 = 98.016g $mole^{-1}$

No of molecules of H_2SO_4 = $\frac{\text{Mass of } H_2SO_4}{\text{Molar Mass of } H_2SO_4} \times 6.02\times 10^{23}$

$= \frac{20}{98.016} \times 6.02 \quad 10^{23}$

$= 1.228\times 10^{23}$

b. H_2SO_4 dissolves in water as follows:

$$H_2SO_4 \longrightarrow 2H^+ + SO_4^{2-}$$

According to equation

1molecule of H_2SO_4 = $2H^+$ ions

1.228×10^{23} molecules of H_2SO_4 $= 2 \times 1.228 \times 10^{23}\ H^+$ ions

$= 2.456\times 10^{23} H^+$ ions

As 1molecule of H_2SO_4 =1 SO_4^{2-} ion

So, 1.228×10^{23} molecule of H_2SO_4 = $1.228\times10^{23}\ SO_4^{2-}$ ions

c. Mass of individual ions $= \frac{\text{No. of ions}}{6.02 \times 10^{23}} \times \text{Molar mass of an ion}$

$$\text{Mass of } H^+ = \frac{2.456 \times 10^{23}}{6.02 \times 10^{23}} \times 1.008$$

$$= 0.411g$$

$$\text{Mass of } SO_4^{2-} = \frac{1.228 \times 10^{23}}{6.02 \times 10^{23}} \times 96$$

$$= 19.58g$$

4.1.6 Solution Stoichiometry

In solutions the most common concentration unit is molarity. The molarity of a solution is simply the numerical value of its concentration in mol/dm^3.

If you read label on the bottle of concentrated H_2SO_4 you will notice 98% H_2SO_4 by mass and also 18M H_2SO_4. What does 18M stand for? This means there are 18 moles of H_2SO_4 in each dm^3 of solution. Similarly, conc. HCl is 37% and 12.1 M HCl. This means there are 12.1 moles of HCl in each dm^3 of solution. We can express the concentration in terms of moles of solute in the given volume of solution.

Molarity is the concentration unit in which amount of solute is expressed in moles and quantity of solution in dm^3.

"Molarity is defined as the number of moles of solute dissolved per dm^3 of solution".

Mathematically,

$$M = \frac{\text{mole of solute}}{\text{dm}^3 \text{ of solution}}$$

Example 4.8

Urea (NH_2CONH_2) is a white solid used as fertilizer and starting material for synthetic plastic. A solution contains 40g urea dissolved in 500cm^3 of solution. Calculate the molarity of this solution.

Solution

Mass of urea = 40g

Molar Mass of urea (NH_2CONH_2) = $14 + 1 \times 2 + 12 + 16 + 14 + 1 \times 2$

= 60g/mol

Moles of urea = $\frac{40g}{60g/mol} = 0.667 mol$

Volume of solution = $\frac{500}{1000} = 0.5dm^3$

Now

$$\text{Molarity} = \frac{\text{mole of solute}}{\text{dm}^3\text{ of solution}}$$

$$\text{Molarity} = \frac{0.667\text{ mol}}{0.5\text{dm}^3}$$

$$= 1.334\text{ M}$$

In solution stoichiometry we use volumes of solutions of known concentration instead of masses of reactants and products and their molarity is used to determine its moles.

Example 4.9

When 250cm^3 of 0.1M $AgNO_3$ solution is added to an excess of NaCl solution. What mass of AgCl will be formed.

Solution

$$AgNO_{3(aq)} + NaCl_{(aq)} \rightarrow AgCl_{(s)} + NaNO_{3(aq)}$$

Find the moles of silver nitrate present in the solution.

As the solution is 0.1M

1000cm^3 of solution contain = 0.1 mol of $AgNO_3$

250cm^3 of solution contain $= \frac{0.1 \times 250}{1000} = 0.025$ mol of $AgNO_3$

Now

1 mol of $AgNO_3$ produces = 1 mol of AgCl

0.025 mol of $AgNO_3$ will produce = 0.025 mol of AgCl

Mass of AgCl produced = moles x molar mass

= 0.025 x 143.5

= 3.59g

When two solutions are mixed, we proceed as follows.

Moles of reactant 1 = M_1V_1 and Moles of reactant 2 = M_2V_2

The ratio between moles of reactants is the same as given by the balanced chemical equation.

$M_1V_1 : M_2V_2 = n_1 : n_2$

Where n_1 and n_2 are moles of reactants in the chemical reaction.

$$\frac{M_1V_1}{M_2V_2} = \frac{n_1}{n_2}$$

In this expression the ratio of two volumes remains the same whether you used volumes in dm^3 or cm^3

$$\frac{M_1V_1}{n_1} = \frac{M_2V_2}{n_2}$$

Example 4.10

What volume of 0.5M sodium sulphate will react with 275cm^3 of 0.25M barium chloride solution to completely precipitate Ba^{2+} in solution.

Solution

$$Na_2SO_{4(aq)} + BaCl_{2(aq)} \rightarrow BaSO_{4(s)} + 2NaCl_{(aq)}$$

$V_1 = ?$ $V_2 = 275cm^3$

$M_1 = 0.5M$ $M_2 = 0.25M$

$n_1 = 1$ $n_2 = 1$

$$\frac{M_1V_1}{n_1} = \frac{M_2V_2}{n_2}$$

$$\frac{0.5 \times V_1}{1} = \frac{0.25 \times 275}{1}$$

$$V_1 = \frac{0.25 \times 275}{0.5}$$

$$V_1 = 137.5cm^3$$

Concept Assessment Exercise 4.4

1. Potassium chlorate ($KClO_3$) is a white solid. It is used in making matches and dyes.

Calculate the molarity of solution that contains. (a) 1.5 moles of this compound dissolved in 250cm³ of solution (b) 75g of this compound dissolved to produce 1.25dm³ of solution. (c) What is the molarity of a 50cm³ sample of potassium chlorate solution that yields 0.25g residue after evaporation of the water.

2. What volume of 0.25M LiOH will completely react with 0.500dm^3 of 0.25M H_2SO_4.

$$2LiOH_{(aq)} + H_2SO_{4(aq)} \rightarrow Li_2SO_{4(aq)} + 2H_2O_{(l)}$$

3. How many grams of NaOH are required to neutralize 40cm^3 of 0.5M HCl solution.

$$NaOH_{(aq)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$$

4.2 LIMITING AND NON LIMITING REACTANTS

When two reactants are mixed for a reaction, usually one of them reacts completely and other reactant does not react completely. **The reactant that is completely consumed in the reaction and limits the amounts of product formed is called limiting reactant and reactant that is left unreacted after the completion of reaction is called non limiting or excess reactant.**

To understand this concept, consider the following reaction

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

When I mole of O_2 and 1 mole of H_2 are mixed, all the H_2 will react completely and O_2 will left unreacted because for 1 mole of H_2, ½ mole of O_2 is required, which is available but for complete reaction of 1 mole of O_2 , 2 moles of H_2 required which are not available that's why H_2 is limiting reactant, and O_2 is non-limiting or excess reactant.

Example 4.11:

Calculate the mass of calcium nitride (Ca_3N_2)prepared from 54.9 grams of Ca and 43.2 grams of N_2

$$3Ca + N_2 \rightarrow Ca_3N_2$$

Solution:

Moles of Ca =54.9/40 =1.37 moles

Moles of N_2 = 43.2/28 = 1.54 moles

3 moles of Ca produce = 1 mole of Ca_3N_2

1 moles of Ca produce = 1/3 moles of Ca_3N_2

1.37 moles of Ca produce =1/3 x 1.37 = 0.457 moles of Ca_3N_2

1 mole of N_2 produces =1 mole of Ca_3N_2

1.54 moles N_2 produce =1.54 moles of Ca_3N_2

Ca produced least amount (0.457 moles of Ca_3N_2) so it is limiting react

Concept Assessment Exercise 4.5

1. How much volume is occupied by marsh gas (CH_4) at STP containing 4.8 $\times 10^{24}$ molecules.
2. Calculate the molecular weight of a gas with the density of 1.25g/dm^3.
3. Calculate molecules of H_2O produced by 500 molecules each of H_2 and O_2 . Which one is the limiting reactant? How much excess reactant is left unreacted? What would happen if molecules of O_2 were doubled?
4. Excess of $AgNO_3$ was added to $FeCl_3$ and 2.02g of AgCl was produced. Calculate amount of $FeCl_3$ produced in the reaction.

4.3 THEORETICAL YIELD, ACTUAL YIELD AND PERCENT YIELD

We adopted an optimistic approach to the amount of product resulting from the chemical reaction. We assume that 100% of the limiting reactant becomes product. **The amount of product as calculated from the balanced chemical equation is called the theoretical yield.** In reality, the amount of products during chemical reactions does not match what the chemical equation shows because some side reactions produce alternative products, some of the product may remain in solution, the reaction may be stopped before completion, etc. Whatever the reason, the fact is that the reaction produces less product than the calculated amount. **Quantity of product produced experimentally in a chemical reaction is called the actual yield**, and the percentage yield is 100 times the ratio of the actual yield to the theoretical yield.

$$\text{Percent yield} = \frac{\text{Actual yield}}{\text{Theoretical yield}} \times 100$$

Example 4.12:

Calculate the percent yield of Ozone that could be produced by 10g of O_2.

Actual yield of O_3 1.05g .

Solution:

$3O_2 \rightarrow 2O_3$

Molar mass of O_3 = 48 g/mol

Mass of O_2 = 10g

Moral mass of O_2 = 32g/mol

Moles of $O_2 = \frac{10}{32} = 0.3125$

3 mol of O_2 give = 2 mol of O_3

1 mol of O_2 gives = $\frac{2}{3}$ mol of O_3

0.3125 mol of O_2 will give = $\frac{10}{32} \times 0.3125 = 0.208$ mol of O_3

Mass of O_3 produced = 0.208 x 48 = 10g

Actual yield = 1.05g of O_3

Percent yield = 1.05/10 x 100 =10.5 %

Concept Assessment Exercise 4.6

1. Determine the amount of Ferric Chloride produced by the reaction of $KMnO_4$, 10 moles of $FeCl_2$ and 22 moles of HCl.

   $KMnO_4 + 5FeCl_2 + 8HCl \rightarrow MnCl_2 + KCl + 5\,FeCl_3 + 4H_2O$

2. Baking soda is commercially prepared by passing ammonia and carbon dioxide through saturated solution of NaCl. If 20g NH_3 and 30g CO_2 produced 40g baking soda than calculate percentage yield

   of baking soda taking NaCl and H_2O in excess?

   $NaCl + H_2O + CO_2 + NH_3 \rightarrow NaHCO_3 + NH_4Cl$

4.4 Importance of stoichiometry in the production and dosage of medicine

In the production of medicines the amount of active ingrident is essential to produce desired effects. Stoichiometry ensures the accuracy of drug synthesis. Any deviation can results in incomplete reaction or contamination with un-reacted reactants or by-products. Stoichiometry allows chemists to precisely control chemical reactions to produce drugs, to ensure its efficiency, effectiveness and safe use. For examples;

i. In the preparation of antibiotics, the stoichiometry ensures that each dose matches the active ingredient and target bacteria.
ii. Use of insulin relies on the stoichiometry to precise control of blood sugar levels.
iii. Stoichiometry determines the concentration of viral antigens in the preparation of vaccine for effective results.

Activity: Synthesis of aspirin

Materials required: Salicyclic acid, acetic anhydride, sulphuric acid, sodium hydrogen carbonate, ice bath, water, filteration set up.

Chemical reaction

$$\underset{\text{Salicyclic acid}}{C_7H_6O_3} + \underset{\text{acetic anhydride}}{(CH_3CO)_2O} \rightarrow \underset{\text{aspirin}}{C_9H_8O_4} + \underset{\text{acetic acid}}{CH_3COOH}$$

Steps:

- Mix reactants in stoichionmetrically calculated amounts (one mole of each reactants) in a flask and add few drops of sulphuric acid to catalyse the reaction.
- Place the flask in ice bath.
- Stir the mixture with a glass rod.
- The flask will be filled with insoluble aspirin.
- When the reaction is over, add sodium hydrogen carbonate solution to neutralize excess acid.
- Filter the aspirin, wash and dry aspirin crystals.
- Calculate the amount of aspirin formed.
- Calculate theoretical yield using stoichionmetry.
- Compare the actual yield obtained experimently with the theoretical yield and assess the efficiency of the synthesis.

This activity helps you to understand how stoichionmetry influences production and dosage of medicine.

Key Points

- A mole is the amount of substance that contains 6.023×10^{23} representative particles.
- One mole of any gas at STP (standard temperature and pressure) occupies a volume of $22.414\ dm^3$. This volume is called Molar volume.

- The reactant that completely reacts in the reaction and limits the amounts of product formed is called limiting reactant
- Percent yield = Actual yield/ theoretical yield x 100.

References for Further Information

- James Brady and John R. Holum, Chemistry, The studies of matter and its changes.
- Theodore L. Brown, H. Eugene LeMay Jr and Bruce E. Bursten,
- Chemistry, The central Science.
- Rose Marie Gallagher and Paul Ingram, Complete chemistry.
- Graham Hill and John Holman, Chemistry in Context
- E. N. Ramesden, Calculations for A-Level chemistry.

Exercise

1. **Choose the correct answer**

(i) Which sample produces most hydrogen by reaction with excess of HCl?

(a) 0.25mol Ca　　(b) 0.25mol Al

(c) 0.25mol Zn　　(d) 0.25 Na

(ii) A flask contains 500 cm^3 of SO_2 at STP. The flask contains SO_2

(a) 40 g　　(b) 100 g

(c) 50 g　　(d) 1.42 g

(iii) When 1 mole of each of the following is completely burnt in oxygen, which will give the greater mass of CO_2?

(a) CO　　(b) Diamond

(c) Ethane　　(d) Methane

(iv) Which one occupies more volume at STP.

(a) 1g O_2　　(b) 1g H_2

(c) 1g CH_4　　(d) 1g NO_2

(v) 0.2 moles of Na_2SO_4, when completely ionized produce Na^+ ions.

(a) 2.4×10^{22}　　(b) 2.4×10^{23}

(c) 1.204×10^{23}　　(d) 0.12×10^{23}

(vi) How much volume of NH_3 gas produced when 3g H_2 react with excess of N_2 at STP.

(a) 24 dm^3　　(b) 2.24dm^3

(c) 2.4 dm^3　　(d) 1.2dm^3

(vii) When equal volumes of SO_2 and O_2 taken for the formation of SO_3, which one will be Left unreacted.

(a) SO_2 (b) O_2

(c) Both (d) Not possible

(viii) 0.1 moles of laughing gas (N_2O) consist of.

(a) 6.022×10^{22} molecules (b) 1.806×10^{23} atoms

(c) 1.204×10^{23} atoms of N (d) All

(ix) Which pair contains equal quantities?

(a) Volume of 28g N_2 and 8g CH_4 at STP

(b) Molecules in 0.1 mole NH_3 and 2.2414 dm^3 O_2 at STP

(c) Mass of 1.204×10^{24} molecules of CO_2 and 4.8×10^{24} atoms of NH_3

(d) Bonds in 56g N_2 and 2 mole CH_4

(x) $2X + 3y \rightarrow 1Z$

When 12 moles of y react with excess of X and give 3 moles of Z, its percentage yield is?

(a) 25% (b) 33.33%

(c) 66% (d) 75%

2. **Give short answer.**

(i) 49 g each of H_2SO_4 and H_3PO_4 have same number of molecules but having different number of atoms.

(ii) Different gases having different masses occupy equal volume at STP.

(iii) One mole of Na and Al has equal No. of atoms but size of atoms are different.

(iv) Limiting reactant is always in lesser quantity in reaction mixture or not.

(v) Amount of product obtained through balance chemical equation is greater than the amount obtained experimentally.

(vi) What are the basic assumption in Stoichiometric calculations?

(vii) 18g of steam has Avogadro's No of molecules but 58.5g of NaCl has not.

(viii) Why 2moles of Na react with 1mole of chlorine gas to produce 1mole of NaCl?

3. **Calculate each of the following quantities.**

(i) Mass in gram of 0.74 mol $KMnO_4$.

(ii) Moles of O atoms in 9.22g $Mg(NO_3)_2$.

(iii) Number of O atoms in 0.037g $CuSO_4.5H_2O$.

(iv) Mass in kg of 2.6×10^{20} molecules of SO_3

(v) Total number of ions in 14.3 g $CaBr_2$.

(vi) Mass in mg of 0.45 mole of $CuCl_2.2H_2O$.

(vii) Mass in grams of 2.78×10^{21} molecules of N_2O_4.

(viii) Volume of SO_2 at STP of 4.8×10^{23} molecules of SO_2.

(ix) Mass in gram of $Ca(NO_3)_2$ having 2×10^{21} ions of Nitrate

(x) Covalent bonds in 22 gram of dry ice.

4. Calcium ion can be precipitated from solution by sodium oxalate.

$Ca^{2+} + Na_2C_2O_4 \rightarrow CaC_2O_4 + 2Na^+$

Is 15 g Ca^{2+} can be completely precipitated by 15 g of sodium oxalate. If Ca^{2+} ions are left in the solution, calculate how much Ca^{2+} ions are left in the solution?

5. 0.05 mol of potassium chlorate heated for a time and its 0.015 mol left. How much KCl produced, also calculate molecules of O_2 produced? $2KClO_3 \rightarrow 2KCl + 3O_2$.

6. Calculate No. of moles of water produce by 5×10^{24} molecules of H_2SO_4 and 20g of NaOH.

7. Formalin is an aqueous solution of formaldehyde (HCHO), used as a preservative for biological specimens. A biologist wants to prepare 1dm^3 of 11.5M formalin. What mass of formaldehyde he requires?

8. What mass of $CaCO_3$, would you use to add to 100cm^3 of 0.5MHCl to completely neutralize acid?

$CaCO_{3(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O_{(l)}$

9. Calculate mass of oxygen required for complete combustion of I mole of gasoline (C_8H_{18}).

10. Graphite is the crystalline form of carbon used in "lead" pencil.

a) How many moles are present in 315mg graphite?

b) How many rbon atoms are in it?

11. Manganese is transition metal essential for the growth of strong bones, Calculate mass of 3.22×10^{20} atoms of manganese found in 1 kilogram of bone?

12. How much mass of excess reactant left after 40.5g of Aluminum metal reacts with 196g of H_2SO_4.

13. Calculate mass of SO_2 that will be produced with 155g of Cu from the roasting of CuS.

$CuS + O_2 \rightarrow Cu + SO_2$

14. SO_2 is air pollutant it contributes to acid rain. Its emission is controlled by absorbing it into a base (NaOH). Calculate mass of SO_2 absorbed by 33g of NaOH.

$SO_2 + 2NaOH \rightarrow Na_2SO_3 + H_2O$

15. Potassium super oxide (KO_2) is used as source of oxygen in re-breathing mask.

$4KO_2 + 2H_2O \longrightarrow 4KOH + 3O_2$

Identify limiting reactant in each of following reactant mixtures.

i) 6.4 moles KO_2 and 2.1 moles of H_2O.

ii) 8.4 moles of KO_2 and 1.5 moles of H_2O.

16. Critically evaluate the importance of the mole concept in understanding chemical reactions.

17. Analyze the relationship between molar volume and Avogadro's number.

18. Compare and contrast the molar volumes of different gases under the same condition of temperature and pressure.

Project:

Develop a series of conversation problems that involve moles, grams, and molecules. Ask students to create step-by-step guide or tutorial explaining how to convert between these units.