Studybeesofficial

Where Minds Pollinate

Class 11
Chemistry

Chapter 4
stoichiometry
Handwritten Notes

CH4: STIOCHIOMETRY

Mole

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 represent 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 moleculer. The atomic mass, formula mass and moleculer weight of a substance in grams are equal to one mole of the substance.

One mole of O atoms = 16g   One mole of O_2 atoms = 32g

One mole of H_2O molecules = 18g   One mole of Na^+ ions = 23g

Molar Mass

Molar Mass is defined as the mass in grams of one mole of a substance. The term molar mass is also used to the mass of a mole of any substance. It is the atomic mass of an atom or the sum of atomic mases of all the atoms in a molecule, an ion or a formula unit.

$H_2SO_4 = 2H + S + 4O$

$= (2\times1) + (1\times32) + (4\times16)$

$= 2 + 32 + 64$

$= 98$ amu (molecular mass)

Molar mass of sulphuric acid (H_2SO_4) = 98g/mol.

Determination of number of moles

$$\text{Number of mole (n)} = \frac{\text{Mass (grams)}}{\text{Molar Mass (g/mol)}}$$

$$\text{Number of mole (n)} = \frac{\text{Number of particles (atoms, molecules, formula units)}}{\text{Particles per mole or Avogrado's no. (mol}^{-1})}$$

Molar Volume

The volume occupied by one mole of an ideal gas at standard temperature and pressure (STP) is called molar volume. Molar Volume is equal to $22.414 dm^3$ or $22414 cm^3$ or 22.414L.

For example,

2.016g of H_2 = 1 mole of H_2

$= 6.022 \times 10^{23}$ molecules of H_2

$= 22.414 dm^3$ volume of H_2 at STP.

16g of CH_4 = 1 mole of CH_4

$= 6.022 \times 10^{23}$ molecules of CH_4

$= 22.414 dm^3$ volume of CH_4 at STP.

Molar Mass and Density of Gases

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

$$\text{Density} = \frac{\text{Molar Mass}}{\text{Molar Volume}}$$

Molar Mass = Density × Molar Volume (V_m)

Stiochiometric Calculations and Mole Ratio

$2H_2$	+ O_2	$\longrightarrow$ $2H_2O$	
2mol	1mol	2mol	(mol)
$2 \times 6.02 \times 10^{23}$	6.02×10^{23}	$2 \times 6.02 \times 10^{23}$	(no. of particles)
4g	32g	36g	(mass)
$2 \times 22.414 dm^3$	$22.414 dm^3$	$2 \times 22.414 dm^3$	(volume)

The amounts of the reatants or the products as given by the balanced chemical equation are called stiochiometric amounts.

Mole-Mole Calculation

In balanced chemical equation, the coefficient used are taken as mole that indicates the stiochiometric relationship in terms of moles.

$$CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)}$$

1mol 2mol 1mol 2mol

Solution Stiochiometry

In solution the most common concentration unit is molarity. The molarity of a solution is simply the numerical value of it concentration in mol/dm^3. Molarity is the concentration unit in which amount of solute is expressed in moles and quantity of solution in dm^3. Molarity is expressed in $moldm^{-3}$ or M. Molarity can be defined as the number of moles of solute dissolved per dm^3 of solution.

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

Limiting and Non-Limiting Reactants

A reactant which is completely consumed earlier leaving behind the other reactant in excess is called limiting reactant. lesser than stiochiometric amount. Controls the chemical reaction Controls the amount of product. Gives least amount of product. The reactant that is unreacted after the completion of reaction is called non-limiting or excess reactant.

Theoritical, Actual and Percent yeild

The amount of the product calculated from balanced chemical equation or produced as a result of chemical reaction is known as yield. The types of yield are • theoritical yield and • Actual yield.

Theoritical yield: the amount of product calculated from the balanced chemical equation is called theoritical yield. It is the maximum amount of product that should be produced according to the balanced chemical equation.

Actual yield: the amount of the product obtained experimentally as a result of chemical reaction is called actual yield. It is also called practical or experimental yield. Actual yield is mostly less than theortical yield.

Percentage yield: The ratio of actual yield to theoritical yield multiplied by 100 gives us percentage yield. A chemist is usually intersted in the efficiency of a reaction. The efficiency of the reaction is expressed in the form of percentage yield.

$$\% \text{ yield} = \frac{\text{Actual yeild}}{\text{theoritical yeild}} \times 100$$

Questions

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

Both H_2SO_4 and H_3PO_4 have same number of molecules because both have the same number of moles (0.5mol). But their chemical composition differ because, Sulphuric acid (H_2SO_4) contains 2 hydrogen, 1 sulphur and 4 oxygen atoms, so the total atoms per molecule are 7 and Phosphoric acid (H_3PO_4) contains 3 hydrogen, 1 phosphurs and 4 oxygen atoms, so the total atoms per molecule are 8. The difference in no. of atoms leads to distinct chemical properties and behaviours.

Different gases having different masses occupy equal volume at STP.

At Standard Temperature and Pressure (STP), equal volumes of different gases occupy the same space because of Avgadro's law. This law states that at the same temperature and pressure, equal volumes of gases contain the same number of molecules. So, even though gas particles have different masses, they still fill the same volume due to this fundamental principal.

CamScanner

One mole of Na and Al has equal no. of atoms but size of atoms are different.
One mole of both sodium (Na) and aluminium (Al) contains the same number of atoms (6.02×10^{23}) but their atomic sizes differ significantly due to position in the periodic table.
Limiting reactant is always in lesser quantity in reaction mixture or not.
The limiting reactant is always present in lesser quantity in the reaction mixture. It determines the maximum amount of product that can be formed. The other reactant, called the excess reactant, remains unreactaed after the reaction.
Amount of product obtained through balance chemical equation is greater than the amount obtained experimentally.
The amount of product obtained through balanced chemical equation (theoretical yield) is greater then the amount obtain experimentally (practical yield) due to following reasons:
- Side reaction/competing reaction
- Reversible reaction
- Incomplete reaction
- Inexperianced worker
- Mechanical Loss of products during seperation by solvent extraction, filtration, distillation and crystallization etc.

Actual yield maybe lesser due to inefficiency during the washing and drying of crystals.
What are the basic assumption in Stiochiometric calculations?
The basic assumptions in stiochiometric calculations are:
- All the reactants are completely converted into products.
- No side reaction occurs.
- The law of conservation of mass and the law of definite proportions are obeyed.

18g of steam has Avogadro's number of molecules but 58.5g of NaCl has not
The difference lies in the molecular composition of the substances:
Steam (H_2O) water vapour has a molecule formula of H_2O. The molar mass of water (H_2O) is approximately 18 g/mol. Avogadro's number (6.022×10^{23}) represents the number of molecules in 1 mole of any substance. So, 18g of steam contains avagadro's number of water molecules.
Sodium Chloride (NaCl) is an ionic compound. Its molar mass is approximately 58.5g/mol However, 58.5g of NaCl does not contain avogadro's no. of molecules. This is becuase NaCl exists as a crystals lattice, where each formula unit represents a repeating pattern of Na^+ and Cl^- ions, rather than individual molecules.

In short, the concept of avogadro's no. applies differently to molecular substances (like water) and ionic compounds (NaCl).

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

The balanced chemical equation for the reaction between sodium (Na) and chlorine (Cl_2) to form sodium chloride (NaCl) is as follows:

$$2Na + Cl_2 \longrightarrow 2NaCl$$

In this equation:

2 moles of Na reacts with 1 mole of Cl_2. The product is 2 moles of NaCl. This balanced equation ensures that the law of conservation of mass is satisfied, meaning that the total number of atoms of each element remains the same before and after the reaction. Sodium (Na) donates one electron to chlorine (Cl), resulting in the formation of the ionic compound sodium chloride (Na Cl)

Mass in gram of 0.74 mol $KMnO_4$

Molar Mass of $KMnO_4$ $= 39 + 55 + 16\times4$

$= 158\,g/mol$

Moles of $KMnO_4$ $= 0.74\ mol$

Mass in grams $=$ Moles $\times$ Molar mass

$= 0.74\,mol \times 158\,g/mol$

$= 116.92\,g$

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

Molar Mass of $Mg(NO_3)_2$ $= 24 + 14\times2 + 16\times6$

$= 148\,g/mol$

Mass of $Mg(NO_3)_2$ $= 9.22\,g$

Moles of $Mg(NO_3)_2$ $= \dfrac{\text{Mass of } Mg(NO_3)_2}{\text{Molar mass of } Mg(NO_3)_2}$

$= \dfrac{9.22}{148}$

$= 0.0623\ mol$

1 mole of $Mg(NO_3)_2$ has O mol $=$ 6 mol of oxygen atoms

0.0623 mol of $Mg(NO_3)_2$ has O $= 0.0623\times6$

$= 0.374\ mol$

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

Molar Mass of $CuSO_4.5H_2O$ $= 63.5 + 32 + 4\times16 + 5\times18$

$= 249.5\, g/mol$

Mass of $CuSO_4.5H_2O$ $= 0.037g$

Moles of $CuSO_4.5H_2O$ $= \dfrac{\text{Mass of } CuSO_4.5H_2O}{\text{Molar mass of } CuSO_4.5H_2O}$

$= \dfrac{0.037}{249.5}$

$= 1.48 \times 10^{-4}$ mol

1 mole of $CuSO_4.5H_2O$ has O mol $= 9$ mol of oxygen atoms

1.48×10^{-4} mol of $CuSO_4.5H_2O$ has O $= 1.48 \times 10^{-4} \times 9$

$= 0.00134$ mol $\times 6.02$

Number of O atoms $= 0.00806 \times 10^{23}$ atoms

$= 8.06 \times 10^{20}$ atoms.

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

Number of SO_3 molecules $= 2.6\times10^{20}$

Molar Mass of SO_3 $= 80\, g/mol$

Mass of SO_3 molecules $= \dfrac{\text{Molar Mass}}{N_A} \times$ Number of molecules

$= \dfrac{80}{6.02\times10^{23}} \times 2.6\times10^{20}$

$= 0.03455g$

$= 3.455 \times 10^{-2}\, g$

$= 3.455 \times 10^{-5}\, kg$

Total number of ions in 14.3g $CaBr_2$

Molar mass of $CaBr_2$ $= 40 + 2\times79.9$

$= 199.8\, g/mol$

Mass of $CaBr_2$ $= 14.3g$

Moles of $CaBr_2$ $= \dfrac{\text{Mass of } CaBr_2}{\text{Molar mass of } CaBr_2}$

$= 0.0716$ mol

$CaBr_2 \longrightarrow Ca^{2+} + 2Br^-$

Total no. of ions $= 3\times0.0716\times6.02\times10^{23}$ $= 1.29\times10^{23}$ ions.

CS CamScanner

Mass in ~~gram~~ mg of 0.45 mol of $CuCl_2 . 2H_2O$

Molar Mass of $CuCl_2 . 2H_2O$ $= 63.5 + 2 \times 35.5 + 18$

$= 152.5 \, g/mol$

Moles of $CuCl_2 . 2H_2O$ $= 0.45 \, mol$

Mass in grams $=$ Molar mass $\times$ Moles

$= 0.45 \times 152.5$

$= 68.625 g$

$= 68.625 \times 1000 \, mg$

$= 68625 \, mg$

Mass in grams of 2.78×10^{21} molecules of N_2O_4

Number of N_2O_4 molecules $= 2.78 \times 10^{21}$

Molar mass of N_2O_4 $= 92 \, g/mol$

Mass of N_2O_4 molecules $= \frac{\text{No. of molecules}}{N_A} \times$ Molar Mass

$= \frac{2.78}{6.02 \times 10^{23}} \times 92$

$= 0.425 g$

Volume of SO_2 at STP of 4.8×10^{23} molecules of SO_2

Number of SO_2 molecules $= 4.8 \times 10^{23}$

Molar Volume of SO_2 at STP $= 22.414 \, dm^3$

Volume of SO_2 molecules $= \frac{\text{Number of molecules}}{N_A} \times$ Molar Volume

$= \frac{4.8 \times 10^{23}}{6.02 \times 10^{23}} \times 22.414$

$= 17.87 \, dm^3$

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

Molar mass of $Ca(NO_3)_2$ $= 40 + 14 \times 2 + 16 \times 6$

$= 164 \, g/mol$

Number of nitrate ions $= 2 \times 10^{21}$

Each $Ca(NO_3)_2$ produces $=$ 2 Nitrate ions

OR,

2 Nitrate ions are present in 1 formula unit of $Ca(NO_3)_2$

2×10^{21} Nitrate ions are present in $Ca(NO_3)_2$ $= 1/2 \times 2 \times 10^{21}$ formula units.

$= 1 \times 10^{21}$ formula units.

Mass of $Ca(NO_3)_2$ = $\frac{\text{Fromula units}}{NA} \times$ Molar Mass

= 0.27g

Covalent Bonds in 22 gram of dry ice

Molar Mass of dry ice (CO_2) = 44g/mol

Mass of dry ice (CO_2) = 22g

$O = C = O$

1 molecule of CO_2 have covelent bonds = 4 bonds

Moles of dry ice = $\frac{\text{Mass of dryice}}{\text{Molar mass}}$

= 0.5 mol

No. of covelent bonds = $4 \times 0.5 \times 6.022 \times 10^{23}$

$= 12.04 \times 10^{23}$

$= 1.204 \times 10^{24}$ bonds

Calcium ion can be precipitated from solution by sodium oxalate.

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

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

Mass of Ca^{2+} = 15g

Mass of $Na_2C_2O_4$ = 15g

No. of Ca^{2+} ions left unreacted = ?

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

40g	134g
40/134g	1g
40/134 × 15g	1 × 15g
4.48g	15g

For 15g sodium oxalate only 4.48g Ca^{2+} ions are required. Hence Ca^{2+} ions are in excess and sodium oxalate is limiting reactant.

Amount of Ca^{2+} ions unreacted = 15 − 4.48 = 10.52g

Number of Ca^{2+} ions left unreacted = $\frac{10.52}{40} \times 6.02 \times 10^{23}$

$= 1.58 \times 10^{23}$ ions.

0.5 mol of potassium chlorate headeted for a time and 0.015 mol left. How much KCl produced, also calculated molecules of O_2 produced?

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

Amount of KCl produced:

No. of moles of potassium chlorate = 0.05 mol

No. of moles of potassium chlorate left unreacted = 0.015 mol

No. of moles of potassium chlorate consumed = 0.05 − 0.015

= 0.035 mol

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

2 mol   2 mol

0.035 mol   0.035 mol

Amount of potassium chloride produced = 0.035 × 74.5

= 2.61g

Number of Molecules of Oxygen:

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

2 mol   3 mol

0.035 mol $3/2 \times 0.035$ mol

0.0525 mol

Number of molecules of oxygen produced = $0.0525 \times 6.02 \times 10^{23}$

= 0.316×10^{23}

= 3.16×10^{22} molecules.

Calculate number of moles of water produced by 5×10^{24} molecules of H_2SO_4 and 20g of NaOH

Number of molecules of H_2SO_4 = 5×10^{24}

Mass of NaOH = 20g

No. of moles of water produced = ?

No. of moles of H_2SO_4 = $\frac{5 \times 10^{24}}{6.02 \times 10^{23}}$ = 8.3 mol

No. of moles of NaOH = $\frac{20}{40}$ = 0.5 mol

$$H_2SO_4 + 2NaOH \longrightarrow Na_2SO_4 + 2H_2O$$

1 mol   2 mol   2 mol

8.3 mol of H_2SO_4 produces water = 2 × 8.3 = 16.6 mol

0.5 mol of NaOH produces water = 0.5 mol

Limiting reactant is NaOH
Number of moles of water produced = 0.5 mol

Formalin is an aqueous solution of formaldehyde ($HCHO_4$), used as a preservative for biological specimens. A biologist wants to prepare $1 dm^3$ of 11.5M formaline. What mass of formaldehyde he requires?

Molarity of formaline = 11.5M
Volume of formalin = $1 dm^3$
Molar mass of formaldehyde ($HCHO$) = 30g/mol
Moles of solute = Molarity × dm^3 of solution
No. of moles ($HCHO$) = 11.5 × 1
= 11.5 mol
Mass of formaldehyde ($HCHO$) = 11.5 × 30
= 345g

What mass of $CaCO_3$ would you use to add to $100cm^3$ of 0.5M HCl to completely neutrilize acid?

$$CaCO_3 + 2HCl \longrightarrow CaCl_2 + CO_2 + H_2O$$

Molarity of HCl solution = 0.5M
Volume of HCl solution = $100cm^3$ = $0.1 dm^3$
Molar Mass of $CaCO_3$ = 100g/mol
Moles of HCl = 0.5 × 0.1 = 0.05 mol

$$\underset{1\,mol}{CaCO_3} + \underset{2\,mol}{2HCl} \longrightarrow CaCl_2 + CO_2 + H_2O$$

2 mol of HCl consumes $CaCO_3$ = 1 mol
0.05 mol of HCl consumes $CaCO_3$ = 1/2 × 0.05 = 0.025 mol
Mass of $CaCO_3$ used by HCl = 0.025 × 100 = 2.5g

Calculate mass of oxygen required for complete combustion of 1 mole of gasoline (C_8H_{18}).

Mole of gasoline = 1 mol
Molar mass of oxygen = 32 g/mol

$$\underset{1\,mol}{C_8H_{18}} + \underset{25/2\,mol}{25/2\,O_2} \longrightarrow 8CO_2 + 9H_2O$$

1 mol of gasoline requires oxygen = 25/2 mol = 12.5 mol
Mass of oxygen consumed by gasoline = 12.5 × 32
= 400g

CamScanner

Graphite is a crystalline form of carbon used in 'lead' pencil.
(a) How many moles are present in 315 mg graphite.
(b) How many carbon atoms are in it?

(a) Atomic mass of graphite (C) = 12 g/mol
Mass of graphite (C) = 315 mg
Moles of graphite (C) = ?
Mass of graphite in grams = 0.315 g
Number of moles of graphite = 0.0263 mol (0.315/12)

(b) Number of atoms of graphite = ?
No. of atoms of graphite = $0.0263 \times 6.02 \times 10^{23}$
$= 1.58 \times 10^{22}$ atoms.

Magnese is transition metal essential for growth of strong bones. Calculate mass of 3.22×10^{20} atoms found in 1 kilogram of bone.

Atomic mass of Mn = 56 g/mol
No. of atoms of Mn = 3.22×10^{20}
Mass of Mn = ?
No. of moles of Mn = $\dfrac{3.22 \times 10^{20}}{6.02 \times 10^{23}}$
= 0.00535 mol
Mass of Mn = 0.005635×56
$= 0.299 \approx 0.3$ g

How much mass of excess reactant left after 40.5g of Aluminium metal reacts with 196g of H_2SO_4?

$$2Al + 3H_2SO_4 \longrightarrow Al_2(SO_4)_3 + 3H_2$$

Mass of Al = 40.5g
Mass of H_2SO_4 = 196g
Mass of excess reotant left behind = ?
No. of moles of Al = $\dfrac{40.5}{27}$ = 1.5 mol

No. of moles of H_2SO_4 = $\dfrac{196}{98}$ = 2 mol

3 mol of H_2SO_4 requires = 2 mol of Al
2 mol of H_2SO_4 requires = $2/3 \times 2$ = 1.33 mol of Al.

Hence Al is in excess and H_2SO_4 is limiting reactant.

No. of moles of excess reactant (Al) left behind $= 1.5 - 1.33$

$= 0.17$ mol

Mass of excess reactant left behind $= 0.17 \times 27$

$= 4.59g$

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

$$CuS + O_2 \longrightarrow Cu + SO_2$$

Mass of Cu $= 155g$

Mass of SO_2 produced = ?

$$CuS + O_2 \longrightarrow Cu + SO_2$$

63.5g 64g

63.5g is produced along with $SO_2 = 64g$

155g Cu is produced along with $SO_2 = \frac{64}{63.5} \times 155$

$= 156.2g$

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.

$$SO_2 + 2NaOH \longrightarrow Na_2SO_3 + H_2O$$

Mass of NaOH $= 33g$

Mass of SO_2 absorbed = ?

Number of moles of NaOH $= \frac{33}{40}$

$= 0.825$ mol

$$SO_2 + 2NaOH \longrightarrow Na_2SO_3 + H_2O$$

2 mol of NaOH absorbs SO_2 = 1 mol of SO_2

0.825 mol of NaOH absorbs $SO_2 = 1/2 \times 0.825$

$= 0.4125$ mol

Mass of SO_2 absorbed $= 0.4125 \times 64g$

$= 26.4g$

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 each of the following reactant mixture.

(i) 6.4 mol KO_2 and 2.1 mol H_2O.

(ii) 8.4 mol KO_2 and 1.5 mol H_2O.

(i) 6.4 mol KO_2 and 2.1 mole H_2O

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

4 mol   2 mol

6.4 mol   2/4 x 6.4 mol

6.4 mol   3.3 mol > 2.1 mol (given)

Hence, KO_2 is excess reactant and limiting reactent is H_2O.

(ii) 8.4 mol KO_2 and 1.5 mol H_2O.

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

4 mol   2 mol

8.4 mol   2/4 x 8.4 mol

8.4 mol   4.2 > 1.5 mol (given)

Hence, KO_2 is excess reactant and limiting reactant is H_2O.