NURTURE

IIT CHEMISTRY

PHYSICAL CHEMISTRY

MOLE CONCEPT

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BASICS OF CHEMISTRY

1. CLASSIFICATION OF MATTER

1.1 Physical classification: It is based on physical state under ordinary conditions of temperature and pressure, matter is classified into the following three types:

(a) Solid **(b) Liquid** **(c) Gas**

(a) Solid: A substance is said to be solid if it possesses a definite volume and a definite shape

E.g. sugar, iron, gold, wood etc.

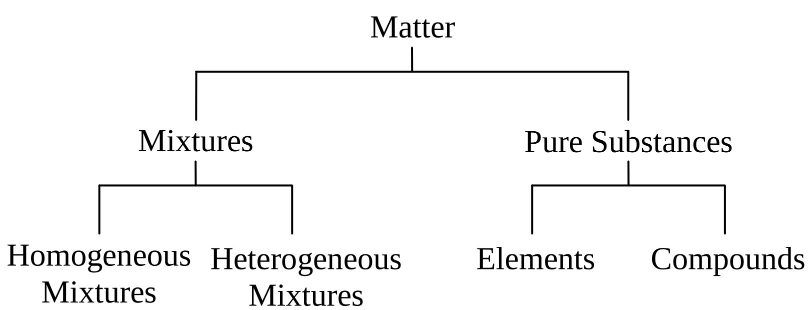
(b) Liquid: A substance is said to be liquid if it possesses a definite volume but not definite shape. They take up the shape of the vessel in which they are put.

E.g. water, milk, oil, mercury, alcohol etc.

(c) Gas: A substance is said to be gas if it neither possesses a definite volume nor a definite shape. This is because they fill up the whole vessel in which they are put.

E.g. hydrogen(H_2), oxygen(O_2), carbon dioxide(CO_2), etc.

1.2 Chemical classification:



On the basis of chemical nature matter is classified into the following two types :

(a) Pure Substance **(b) Mixture**

(a) Pure Substance: When all constituent particles of a substance are same in chemical nature, it is said to be a pure substance. Two type of pure substances:

(i) Element **(ii) Compound**

(i) Element: an element consist of only one type of atoms. These particles may exist as Atoms or molecules. E.g. O_2, P_4, S_8, etc.

(ii) Compound: When two or more atoms of different elements combine together in a definite ratio. E.g. water, ammonia, carbon dioxide, sugar, etc.

(b) Mixture: A mixture contains many types of particles. A mixture contains particles of two or more pure substances which may be present in it in any ratio. Hence, their composition is variable. Pure substances forming mixture are called its components. Many of the substances present around you are mixtures. For example, sugar solution in water, air, tea, etc., are all mixtures. Two types of mixtures:

(i) Homogeneous mixture **(ii) Heterogeneous mixture**

(i) **Homogeneous mixture:** The components completely mix with each other. This means particles of components of the mixture are uniformly distributed throughout the bulk of the mixture and its composition is uniform throughout. E.g.: Sugar solution, air

(ii) **Heterogeneous mixture:** In a heterogeneous mixture, the composition is not uniform throughout and sometimes different components are visible. E.g.: mixtures of salt and sugar, grains and pulses along with some dirt (often stone pieces)

2. INTRODUCTION:

There are a large number of objects around us which we can see and feel. It was John Dalton who firstly developed a theory on the structure of matter, later on which is known as Dalton's atomic theory.

2.1. DALTON'S ATOMIC THEORY:

(i) Each element is composed of extremely small particles called atoms which can take part in chemical combination.

(ii) All atoms of a given element are identical i.e., atoms of a particular element are all alike but differ from atoms of other elements.

(iii) Atoms of different elements possess different properties (including different masses).

(iv) Atoms are indestructible i.e., atoms are neither created nor destroyed in chemical reactions.

(v) Atoms of elements combine to form molecules and compounds are formed when atoms of more than one element combine.

(vi) In a given compound, the relative number and kind of atoms is constant.

2.2. **Atomic mass:** It is the average relative mass of atom of element as compared with times the mass of an atom of carbon-12 isotope.

$$\text{Atomic mass} = \frac{\text{Average mass of an atom}}{1/12 \times \text{Mass of an atom of } C^{12}}$$

2.3. **Gram atomic mass (GAM):** Atomic mass of an element expressed in grams is called Gram atomic mass or gram atom or mole atom.

(i) $\text{Number of gram atoms} = \dfrac{\text{Mass of an element}}{\text{GAM}}$

(ii) Mass of an element in g = No. of gram atoms × GAM

(iii) Number of atoms in 1 GAM = 6.02×10^{23}

Number of atoms in a given substance = No. of gram atoms × 6.02×10^{23}

(iv) $\text{Number of atoms in 1 g of element} = \dfrac{\text{Mass}}{\text{GAM}}$

(v) $\text{Mass of one atom of the element (in g)} = \dfrac{\text{GAM}}{6.02 \times 10^{23}}$

2.4. Molecular mass: Molecular mass of a molecule, of an element or a compound may be defined as a number which indicates how many times heavier is a molecule of that element or compound as compared with $\frac{1}{12}$ of the mass of an atom of carbon-12. Molecular mass is also expressed in a.m.u.

$$\text{Molecular mass} = \frac{\text{Mass of one molecule of the substance}}{1/12 \times \text{Mass of one atom of C-12}}$$

Actual mass of one molecule = Mol. mass (in amu) × 1.66 × 10^{-24} g

Molecular mass of a substance is the additive property and can be calculated by adding the atomic masses of atoms present in one molecule.

2.5. Gram molecular mass (GMM) : Molecular mass of an element or compound when expressed in g is called its gram molecular mass, gram molecule or mole molecule.

$$\text{Number of gram molecules} = \frac{\text{Mass of substance}}{\text{GMM}}$$

Mass of substance in g = No. of gram molecules × GMM

Element	R.A.M. (Relative Atomic Mass)	Mass of one atom	Gram Atomic mass /weight
N	14	14 amu	14 gm
He	4	4 amu	4 gm
C	12	12 amu	12 gm

2.6. Mole

One mole of any substance contains a fixed number (6.023×10^{23}) of any type of particles (atoms or molecules or ions) and has a mass equal to the atomic or molecular weight, in grams. Thus it is correct to refer to a mole of helium, a mole of electrons or a mole of any ion, meaning respectively Avogadro's number of atoms, electrons or ions.

Methods of Calculations of mole:

(1) If no. of some species is given, then no. of moles = $\frac{\text{Given no}}{N_A}$

(2) If weight of a given species is given, then no. of moles = $\frac{\text{Given wt.}}{\text{Atomic wt.}}$ (for atoms),

or = $\frac{\text{Given wt.}}{\text{Molecular wt.}}$ (for molecules)

(3) If volume of a gas is given along with its temperature (T) and pressure (P).

$PV = nRT$ (n : Number of moles of gas)

P (Pressure of gas): Pressure of the gas is the force exerted by the gas per unit area of the walls of the container in all directions.

$$\text{Thus, Pressure (P)} = \frac{\text{Force(F)}}{\text{Area(A)}} = \frac{\text{Mass(m)}\times\text{Acceleration(a)}}{\text{Area(A)}}$$

Name	Symbol	Value
Bar	bar	1 bar = 10^5 Pa
Atmosphere	atm	1 atm = 1.01325×10^5 Pa
Torr	Torr	1 Torr = $\frac{101325}{760}$ Pa $\times$ 133.322 Pa
millimeter of mercury	mm Hg	1 mm Hg = 133.322 Pa

V (Volume of gas): Volume is expressed in liters (L), milliliters (mL) or cubic centimeters (cm^3), cubic meters (m^3) .

$1\ m^3 = 10^3\ dm^3 = 10^6 cm^3 = 10^6\ mL = 10^3\ L$

T (Temperature of gas): S.I. unit of temperature is Kelvin (K).

$$T(K) = t(^oC) + 273.15$$

R (Universal gas constant) : Values of R = 0.082 $LatmK^{-1}mol^{-1}$
=8.314 $JK^{-1}mol^{-1}$
=1.987 $CalK^{-1}mol^{-1}$

Note : 1 mole of atom is also termed as 1 g–atom
1 mole of ions is also termed as 1 g–ion
1 mole of molecule is also termed as 1 g–molecule

Ex.1 How much time (in years) would it take to distribute one Avogadro number of wheat grains if 10^{10} grains are distributed each second?

Ans. 1.9×10^6 years (approx)

Sol. 10^{10} grains are distributed in 1 second

6.02×10^{23} grains are distributed in $\frac{6.02 \times 10^{23}}{10^{10}}$ sec = $\frac{6.02 \times 10^{23}}{10^{10} \times 60 \times 60 \times 24 \times 365}$ years

= 1.9×10^6 years (approx.)

Ex.2 How many atoms are there in 100 amu of He ?

Ans. 25

Sol. We know that, 1 amu = $\frac{1}{12}$ × weight of one ^{12}C atom

or weight of one ^{12}C atom = 12 amu (at. wt. of C = 12 amu).
Similarly, as the atomic weight of He is 4
weight of one He atom = 4 amu.

Thus, the number of atoms in 100 amu of He = $\frac{100}{4}$ = 25.

Ex.3 The weight of one atom of Uranium is 238 amu. Its actual weight in gm is ______ :

Ans. 396.74×10^{-4}

Sol. Weight of aone atom = 238 amu

= $238 \times 1.667 \times 10^{-24}$

= 396.74×10^{-4}

Ex.4 Calculate the number of molecules in a drop of water weighing 0.09 g.

Ans. 3.01×10^{21} molecules of H_2O

Sol. number of mole = $\frac{0.09}{18}$

so number of molecules = $\frac{0.09}{18} \times N_A = \;= 3.01 \times 10^{21}$.

Ex.5 A sample of ethane has the same mass as 10.0 million molecules of methane. How many C_2H_6 molecules does the sample contain?

Ans. 5.34×10^6

Sol. Let the number of C_2H_6 molecules in the sample be n. As given, mass of C_2H_6 = mass of 10^7 molecules of CH_4

$$\frac{n}{N_A} \times \text{mol. wt. of } C_2H_6 = \frac{10^7}{N_A} \times \text{mol. wt. of } CH_4$$

$$\frac{n}{N_A} \times 30 = \frac{10^7}{N_A} \times 16$$

$n = 5.34 \times 10^6$.

Ex.6 If, from 10 moles NH_3 and 5 moles of H_2SO_4 , all the H-atoms are removed in order to form H_2 gas, then find the number of H_2 molecules formed.

Ans. 20 N_A

Sol. 10 mole NH_3 have mole of 'H' atom = 10 × 3

5 mole of H_2SO_4 have mole of 'H' atom = 10

Total mole of 'H' atom = 40

mole of H_2 = 20

Ex.7 The weight of 350 mL of a diatomic gas at 0ºC and 2 atm pressure is 1 g. The weight of one atom is :

Ans. 16 amu

Sol. PV = nRT; $n = \frac{PV}{RT}$

$$n = \frac{2 \times 0.350}{0.0821 \times 273} =$$

$$n = \frac{\text{Weight}}{\text{Atomic mass}}$$

Atomic mass = 16 amu

Ex.8 Oxygen is present in a 1-litre flask at a pressure of 7.6×10^{-10} mm of Hg at 0ºC. Calculate the number of oxygen molecules in the flask.

Ans. 0.44×10^{-13} .

Sol. Pressure = 7.6×10^{-10} mm
= 0.76×10^{-10} cm
= atm (1 atom = 76 cm) = 10^{-12} atm.
Volume = 1 litre, R = 0.0821 lit. atm/K/mole, temperature = 273 K.

We know that PV = nRT or n = $\frac{pV}{RT}$

$$n = \frac{10^{-12} \times 1}{0.082 \times 273} = 0.44 \times 10^{-13}$$

Ex.9 Equal volumes of oxygen gas and a second gas weigh 1.00 and 2.375 grams respectively under the same experimental conditions. Which of the following is the unknown gas?
(A) NO (B) SO_2 (C) CS_2 (D) CO

Ans. (C)

Sol. Moles of O_2 = Moles of X(unknown gas)

$$\frac{1}{32} = \frac{2.375}{M_X}$$

$M_X = 76$

Do yourself-1:

1. The number of molecules in 16 g of methane is :

2. A sample of aluminium has a mass of 54.0 g. What is the mass of the same number of magnesium atoms? (At. wt. Al = 27, Mg = 24)
(A) 12 g (B) 24 g (C) 48 g (D) 96 g

3. Find the total number of H, S and 'O' atoms in the following:
(i) 196 gm H_2SO_4 (ii) 196 amu H_2SO_4
(iii) 5 mole $H_2S_2O_8$ (iv) 3 molecules $H_2S_2O_6$.

4. The volume of a gas at 0º C and 700 mm pressure is 760 cc. The number of molecules present in this volume is:

5. Four 1-1 liter flasks are separately filled with the gases H_2, He, O_2 and O_3 at the same temperature and pressure. The ratio of total number of atoms of these gases present in different flask would be:
(A) 1 : 1 : 1 : 1 (B) 1 : 2 : 2 : 3 (C) 2 : 1 : 2 : 3 (D) 3 : 2 : 2 : 1

6. The weight of 2.01×10^{23} molecules of CO is–
(A) 9.3 g (B) 7.2 g (C) 1.2 g (D) 3 g

7. How many moles of e^- weight one Kg :
(A) 6.023×10^{23} (B) $\frac{1}{9.108} \times 10^{31}$ (C) $\frac{6.023}{9.108} \times 10^{54}$ (D) $\frac{1}{9.108 \times 6.023} \times 10^{8}$

3. LAWS OF CHEMICAL COMBINATION:

Antoine Lavoisier, John Dalton and other scientists formulate certain laws concerning the composition of matter and chemical reactions. These laws are known as the law of chemical combination.

3.1 THE LAW OF CONSERVATION OF MASS:

It is given by Antoine Lavoisier.
In a chemical change total mass remains conserved that is mass before reaction is always equal to mass after reaction.
Example:

$$H_2\,(g) + \frac{1}{2}O_2\,(g) \rightarrow H_2O(\ell)$$

Before reaction initially	1 mole	$\frac{1}{2}$ mole	
After the reaction	0	0	1 mole

mass before reaction = mass of 1 mole H_2 (g) + mass of $\frac{1}{2}$ mole O_2 (g)

= 2 + 16 = 18 g

mass after reaction = mass of 1 mole water = 18 g

3.2 LAW OF CONSTANT OR DEFINITE PROPORTION:

It is given by Proust. All chemical compounds are found to have constant composition irrespective of their method of preparation or sources.

Example: In water (H_2O), Hydrogen and Oxygen combine in 2 : 1 molar ratio, the ratio remains constant whether it is tap water, river water or sea water or produced by any chemical reaction.

Ex.10 1.80 g of a certain metal burnt in oxygen gave 3.0 g of its oxide. 1.50 g of the same metal heated insteam gave 2.50 g of its oxide. Show that these results illustrate the law of constant proportion.

Sol. In the first sample of the oxide,

wt. of metal = 1.80 g,

wt. of oxygen = (3.0 – 1.80) g = 1.2 g

$$\frac{\text{wt. of metal}}{\text{wt. of oxygen}} = \frac{1.80\text{g}}{1.2\text{g}} = 1.5$$

In the second sample of the oxide,

$$\frac{\text{wt. of metal}}{\text{wt. of oxygen}} = \frac{1.50\text{g}}{1\text{g}} = 1.5$$

Thus, in both samples of the oxide the proportions of the weights of the metal and oxygen are fixed. Hence, the results follow the law of constant proportion.

3.3 THE LAW OF MULTIPLE PROPORTIONS:

It is given by Dalton.

When one element combines with the other element to form two or more different compounds, the mass of one element, which combines with a constant mass of the other, bear a simple ratio to one another.

Note: Simple ratio here means the ratio between small natural numbers, such as 1: 1, 1: 2, 1: 3, Later on this simple ratio becomes the valency and then oxidation state of the element.

Example: Carbon and Oxygen when combine, can form two oxides, CO (carbon monoxide), CO_2(Carbon dioxides)

In CO, 12 g carbon combined with 16 g of oxygen.

In CO_2, 12 g carbon combined with 32 g of oxygen.

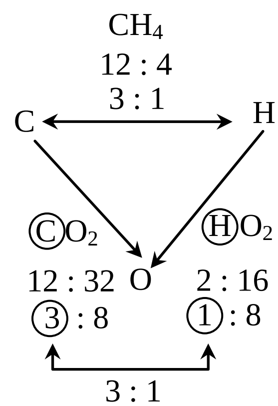
Thus, we can see the mass of oxygen which combine with a constant mass of carbon (12 g) bear simple ratio of 16 : 32 or 1 : 2.

3.4 LAW OF RECIPROCAL PROPORTION:

It is given by Richter.

The ratio of the weights of two elements A and B which combine separately with a fixed weight of the third element C is either the same or simple ratio of the weights in which A and B combine directly with each other.

Example:



Ex.11 Ammonia contains 82.35% of nitrogen and 17.65% of hydrogen. Water contains 88.90% of oxygen and11.10% of hydrogen. Nitrogen trioxide contains 63.15% of oxygen and 36.85% of nitrogen. Show that these data illustrate the law of reciprocal proportions.

Sol. In NH_3, 17.65g of H combine with N = 82.35g

1 g of H combine with N $= \dfrac{82.35}{17.65}$ g = 4.67 g

In H_2O, 11.10 g of H combine with O = 88.90 g

1 g of H combine with O $= \dfrac{88.90}{11.10}\,g = 8.01g$

Ratio of the weights of N and O which combine with fixed weight (=1g) of H
= 4.67 : 8.01 = 1 : 1.7

In N_2O_3, ratio of weights of N and O which combine with each other =36.85 : 63.15
= 1 : 1.7

Thus the two ratios are the same. Hence it illustrates the law of reciprocal proportions.

3.5 GAY-LUSSAC'S LAW OF COMBINING VOLUME:

According to him elements combine in a simple ratio of atoms, gases combine in a simple ratio of their volumes provided all measurements should be done in the same temperature and pressure

$$H_2(g) + Cl_2(g) \longrightarrow 2HCl$$
1 vol 1 vol 2 vol

3.6 AVOGADRO'S H YPOTHESIS:

Equal volumes of polyatomic all gases have equal number of molecules (not atoms) at same temperature and pressures conditions.

S.T.P. (Standard Temperature and Pressure)

At S.T.P. condition:

Temperature = 0°C or 273 K

Pressure = 1 bar

and volume of one mole of gas at STP is found to be equal to 22.7litres which is known as molar volume.

4. STOICHIOMETRY AND STOICHIOMETRIC CALCULATIONS

The word 'stoichiometry' is derived from two Greek words — *stoicheion*(meaning, *element*) and *metron*(meaning, *measure*).Stoichiometry, thus, deals with the calculation of masses (sometimes volumes also) of the reactants and the products involved in a chemical reaction

Example: When potassium chlorate ($KClO_3$) is heated it gives potassium chloride (KCl) and oxygen (O_2).

$KClO_3 \xrightarrow{\Delta} KCl + O_2$ (unbalanced chemical equation)

$2KClO_3 \xrightarrow{\Delta} 2\,KCl + 3O_2$ (balanced chemical equation)

- Remember a balanced chemical equation is one which contains an equal number atoms of each element on both sides of equation.

4.1 Interpretation of balanced chemical equations:

Once we get a balanced chemical equation then we can interpret a chemical equation by following ways

(a) Mass - mass analysis

(b) Mass - volume analysis

(c) Mole - mole analysis

(a) Mole - mole analysis :

This analysis is very much important for quantitative analysis point of view.

Now consider again the decomposition of $KClO_3$.

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

In very first step of mole-mole analysis you should read the balanced chemical equation like **2 moles $KClO_3$ on decomposition gives you 2 moles KCl and 3 moles O_2** and from the stoichiometry of reaction we can write

$$\frac{\text{Moles of KClO}_3}{2} = \frac{\text{Moles of KCl}}{2} = \frac{\text{Moles of O}_2}{3}$$

Now for any general balance chemical equation like

$a\,A + b\,B \longrightarrow c\,C + d\,D$

you can write.

$$\frac{\text{Moles of A reacted}}{a} = \frac{\text{Moles of B reacted}}{b} = \frac{\text{Moles of C produced}}{c} = \frac{\text{Moles of D produced}}{d}$$

(b) Mass - mass analysis :

Consider the reaction $2\,KClO_3 \longrightarrow 2KCl + 3O_2$ According to stoichiometry of the reaction

or $\dfrac{\text{Mass of KClO}_3}{\text{Mass of KCl}} = \dfrac{2\times122.5}{2\times74.5}$ $\qquad$ $\dfrac{\text{Mass of KClO}_3}{\text{Mass of O}_2} = \dfrac{2\times122.5}{3\times32}$

Ex.12 Consider the balanced reaction

$2Cl_2O_7 \longrightarrow 4ClO_2 + 3O_2$ (Cl = 35.5)

What can be concluded from the coefficients of species in this balanced equation?

(A) For this reaction, exactly 2 g of Cl_2O_7 must be taken to start the reaction

(B) For this reaction, exactly 2 mol of Cl_2O_7 must be taken to start the reaction

(C) Mole ratio of Cl_2O_7 , ClO_2 and O_2 during a chemical reaction at any instant are 2, 4 and 3 respectively

(D) The ratio of change in number of moles of Cl_2O_7 , ClO_2 and O_2 is 2 : 4 : 3

Ans. (D)

Sol. It follows directly from definition of stoichiometry.

Ex.13 Calculate the weight of iron which will be converted into its oxide by the action of 36 g of steam.

(Given : $3Fe + 4H_2O \longrightarrow Fe_3O_4 + H_2$)

Ans. 84 g

Sol. Mole ratio of reaction suggests,

Mole of Fe = $\dfrac{3}{4}$ mol of H_2O

$= \dfrac{3}{4}\times\dfrac{36}{18} = \dfrac{3}{2}$

wt. of Fe = $\dfrac{3}{2}\times56 = 84$ g

Ex.14 When Dinitrogen pentaoxide (N_2O_5, a white solid) is heated, it decomposes into nitrogen dioxide and oxygen.

If a sample of N_2O_5 produces 1.6 g O_2, then how many grams of NO_2 are formed ?

$$N_2O_5(s) \longrightarrow NO_2(g) + O_2(g) \qquad \text{(not balanced)}$$

(A) 9.2 g (B) 4.6 g (C) 2.3 g (D) 18.4 g

Ans. (A)

Sol. $N_2O_5(s) \longrightarrow 2NO_2(s) + \frac{1}{2}O_2$ (Balanced reaction)

$$\frac{\text{Mole of } O_2}{1/2} = \frac{\text{Mole of } NO_2}{2}$$

$$\frac{1.6}{32} \times 2 \times 2 = \text{Mole of } NO_2 = 0.2$$

wt of $NO_2 = 0.2 \times 46 = 9.2$ g.

(c) Mass - volume analysis :

Now again consider decomposition of $KClO_3$

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

mass volume ratio : 2×122.5 g : 2×74.5 g : 3×22.4 L at STP

we can use two relation for volume of oxygen

$$\frac{\text{Mass of } KClO_3}{\text{volume of } O_2 \text{at STP}} = \frac{2 \times 122.5\text{g}}{3 \times 22.4\text{L}} \qquad \text{....(i)}$$

and $$\frac{\text{Mass of } KCl}{\text{volume of } O_2 \text{ at STP}} = \frac{2 \times 74.5\text{g}}{3 \times 22.4\text{L}} \qquad \text{....(ii)}$$

Ex.15 When oxygen gas is passed through Siemen's ozoniser, it completely gets converted into ozone gas. The volume of ozone gas produced at 1 atm and 273K, if initially 96 g of oxygen gas was taken, is :

(A) 44.8 L (B) 89.6 L (C) 67.2 L (D) 22.4 L

Ans. (A)

Sol. $3O_2 \longrightarrow 2O_3$

Mole $= \frac{96}{32} = 3$ mole = 2

Volume of O_3 gas at 1 atm and 273K = $2 \times 22.4 = 44.8$ L

Do yourself-2:

1. Assuming 100% yield of the reaction, how many moles of $NaHCO_3$ will produce 448 mL of CO_2 gas at STP according to the reaction :

$$NaHCO_3 \xrightarrow{\Delta} Na_2CO_3 + CO_2 + H_2O \text{ (unbalanced)}$$

(A) 0.04 (B) 0.4 (C) 4 (D) 40

2. Calculate the residue obtained on strongly heating 2.76 g Ag_2CO_3.

$$Ag_2CO_3 \xrightarrow{\Delta} 2Ag + CO_2 + \frac{1}{2}O_2$$

3. For the reaction $2P + Q \longrightarrow R$, 4 mol of P and excess of Q will produce :

(A) 8 mol of R (B) 5 mol of R (C) 2 mol of R (D) 1 mol of R

4. If 1.5 moles of oxygen combine with Al to form Al_2O_3, the weight of Al used in the reaction is:

(A) 27 g (B) 40.5 g (C) 54g (D) 81 g

5. How many liters of CO_2 at STP will be formed when 0.01 mol of H_2SO_4 reacts with excess of Na_2CO_3 .

$$Na_2CO_3 + H_2SO_4 \longrightarrow Na_2SO_4 + CO_2 + H_2O$$

(A) 22.7 L (B) 2.27 L (C) 0.227 L (D) 1.135 L

4.2 LIMITING REAGENT:

Many a time, reactions are carried out with the amounts of reactants that are different than the amounts as required by a balanced chemical reaction. In such situations, one reactant is in more amount than the amount required by balanced chemical reaction. The reactant which is present in the least amount gets consumed after sometime and after that further reaction does not take place whatever be the amount of the other reactant. Hence, the reactant, which gets consumed first, limits the amount of product formed and is, therefore, called the limiting reagent.

The reactant which consumed first into the reaction when we are dealing with balance chemical equation then if number of moles of reactants are not in the ratio of stoichiometric coefficient of balanced chemical equation, then there should be one reactant which should be limiting reactant.

Ex.16 Six mole of Na_2CO_3 is 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	3 mol	6 mol	
given mole ratio	1	:	2
Stoichiometric coefficient ratio	1	:	2

See here given number of moles of reactants are not in stoichiometric coefficient ratio. Therefore there should be one reactant which consumed first and becomes limiting reagent.

But the question is how to find which reactant is limiting, it is not very difficult you can easily find it. According to the following method.

How to find limiting reagent:

Step : I

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

Step : II

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

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)

∴ HCl is limiting reagent

From Step III

From $\frac{\text{Mole of HCl}}{2} = \frac{\text{Mole of } CO_2 \text{ produced}}{1}$

∴ Mole of CO_2 produced = 2 moles

∴ Volume of CO_2 produced at S.T.P. = 2 × 22.7 = 45.4 L

Ex.17 In the reaction $4A + 2B + 3C \longrightarrow A_4B_2C_3$ what will be the number of moles of product formed, starting from 2 moles of A, 1.2 moles of B & 1.44 moles of C :

(A) 0.5 (B) 0.6 (C) 0.48 (D) 4.64

Ans. (C)

Sol.

	4A	+ 2B	+ 3C ⟶	$A_4B_2C_3$
Initial mole	2	1.2	1.44	0
final mole			0	0.48

C is limiting reagent.

moles of $A_4B_2C_3$ is 0.48.

Ex.18 A 5 g mixture of SO_2 and O_2 gases is reacted to form SO_3 gas. What should be the mass ratio of SO_2 and O_2 gases in mixture to obtain maximum amount of SO_3gas :

(A) 4 : 1 (B) 3 : 2 (C) 2 : 3 (D) 1 : 4

Ans. (A)

Sol. For maximum amount of product, the reactants should be present in their stoichiometric ratio.

$$2SO_2\,(g) + O_2\,(g) \longrightarrow 2SO_3\,(g)$$

mass x $5-x$

mole $\frac{x}{64}$ $\frac{5-x}{32}$

So, $\frac{\left(\frac{x}{64}\right)}{\left(\frac{5-x}{32}\right)} = 2:1$

Therefore, x = 4

$m_{SO2} : m_{O2} = 4 : 1$.

Ex.19 Calculate the weight of FeO from 4 g VO and 5.75 g of Fe_2O_3. Also report the limiting reactant.

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

Ans. Weight of FeO formed = 5.17 g

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

Moles before reaction $\quad \frac{4}{67} \quad \frac{5.75}{160} \quad 0 \quad 0$

$= \quad 0.5970 \quad 0.03590$

Moles after reaction $\quad (0.05970–0.0359) \quad 0 \quad \left(\frac{6}{5}\times 0.0359\right) \quad \left(\frac{1}{3}\times 0.0359\right)$

As 2 moles of VO react with 3 moles of Fe_2O_3

$\therefore$ 0.05970 g moles of VO = $\frac{3}{2}$ 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 = $\frac{6}{3}$ 0.0359

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

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

Do yourself-3:

1. 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?

2. How many mole of $Zn(FeS_2)$ can be made from 2 mole zinc, 3 mole iron and 5 mole sulphur.

(A) 2 mole (B) 3 mole (C) 4 mole (D) 5 mole

3. Calculate the amount of Ni needed in the Mond's process given below

$Ni + 4CO \longrightarrow Ni(CO)_4$

If CO used in this process is obtained through a process, in which 6 g of carbon is mixed with 44 g CO_2. (Ni = 59 u)

(A) 14.675 g (B) 29 g (C) 58 g (D) 28 g

4. 0.5 mole of H_2SO_4 is mixed with 0.2 mole of Ca $(OH)_2$. The maximum number of moles of $CaSO_4$ formed is :

(A) 0.2 (B) 0.5 (C) 0.4 (D) 1.5

5. The mass of Na_2SO_4 produced from 196 gram of H_2SO_4 and 1 mole of NaOH.

(A) 49 g (B) 98 g (C) 61 g (D) 34.3 g

4.3 PRINCIPLE OF ATOM CONSERVATION (POAC):

Infect POAC is nothing but the conservation of mass, expressed before in the concepts of atomic theory. And if atoms are conserved, moles of atoms shall also be conserved.
The principle is fruitful for the students when they don't get the idea of balanced chemical equation in the problem.
This principle can be under stand by the following example.
Consider the decomposition of $KClO_3$ (s) $\rightarrow$KCl (s) + O_2 (g) (unbalanced chemical react ion)
Apply the principle of atom conservation (POAC) for K atoms.
Moles of K atoms in reactant = moles of K atoms in products
or moles of K atoms in $KClO_3$ = moles of K atoms in KCl
Now, since 1 molecule of $KClO_3$ contains 1 atom of K
or 1 mole of $KClO_3$ contains 1 mole of K, similarly 1 mole of KCl contains 1 mole of K
Thus, moles of K atoms in $KClO_3$ = 1 × moles of $KClO_3$
and moles of K atoms in KCl = 1 × moles of KCl
$\therefore$ moles of $KClO_3$ = moles of KCl

or $$\frac{\text{wt. of } KClO_3 \text{ in g}}{\text{mol. wt. of } KClO_3} = \frac{\text{wt. of KCl in g}}{\text{mol. wt. of KCl}}$$

* The above equation gives the mass-mass relationship between $KClO_3$ and KCl which is important in stoichiometric calculations.
Again, applying the principle of atom conservation for O atoms,
moles of O in $KClO_3$ = 3 × moles of $KClO_3$
moles of O in O_2 = 2 × moles of O_2
$\therefore$ 3 × moles of $KClO_3$ = 2 × moles of O_2

or $$\frac{\text{wt. of } KClO_3}{\text{mol. wt. of } KClO_3} = 2 \times \frac{\text{vol. of } O_2 \text{ at NTP}}{\text{standard molar vol.(22.4 lt)}}$$

* The above equations thus give the mass-volume relationship of reactants and products.

Ex.20 27.6g K_2CO_3 was treated by a series of reagents so as to convert all of its carbon to $K_2Zn_3[Fe(CN)_6]_2$. Calculate the weight of the product.
[mol. wt. of K_2CO_3 = 138 and mol. wt. of $K_2Zn_3[Fe(CN)_6]_2$ = 698]

Ans. 11.6 g

Sol. Here we have not knowledge about series of chemical reactions but we known about initial reactant and final product accordingly

$$K_2CO_3 \xrightarrow[\text{Steps}]{\text{Several}} K_2Zn_3[Fe(CN)_6]_2$$

Since C atoms are conserved, applying POAC for C atoms,
Moles of C in K_2CO_3 = moles of C in $K_2Zn_3[Fe(CN)_6]_2$
1 × moles of K_2CO_3 = 12 × moles of $K_2Zn_3[Fe(CN)_6]_2$
($\because$ 1 mole of K_2CO_3 contains 1 moles of C)

$$\frac{\text{wt. of } K_2CO_3}{\text{mol. wt. of } K_2CO_3} = 12 \frac{\text{wt. of the product}}{\text{mol. wt. of product}}$$

wt. of $K_2Zn_3[Fe(CN)_6]_2$ = $\frac{27.6}{138} \frac{698}{12}$ = 11.6 g

Ex.21 In a gravimetric determination of P of an aqueous solution of dihydrogen phosphate in $H_2PO_4^-$ is treated with a mixture of ammonium and magnesium ions to precipitate magnesium ammonium phosphate, $Mg(NH_4)PO_4.6H_2O$. This is heated and decomposed to magnesium pyrophosphate, $Mg_2P_2O_7$. A solution of $H_2PO_4^-$ yielded 2.054 g of ($Mg_2P_2O_7$). What weight of NaH_2PO_4 was present originally?

Ans. 2.22 g

Sol. $NaH_2PO_4 + Mg^{2+} + NH_4^+ + \longrightarrow Mg(NH_4)PO_4.6H_2O \xrightarrow{\Delta} Mg_2P_2O_7$

As P atoms are conserved, applying POAC for P atoms, moles of P in NaH_2PO_4 = Moles of P in $Mg_2P_2O_7$

$\Rightarrow 1 \times$ Moles of $NaH_2PO_4 = 2 \times$ Moles of $Mg_2P_2O_7$

$$\therefore \quad \frac{W_{NaH_2PO_4}}{M_{NaH_2PO_4}} = 2 \times \frac{W_{Mg_2P_2O_7}}{M_{Mg_2P_2O_7}} \Rightarrow \frac{W_{NaH_2PO_4}}{120} = 2 \times \frac{2.054}{222}$$

$$\therefore \quad W_{NaH_2PO_4} = 2.22 \text{ g}$$

4.4 PERCENTAGE YIELD:

In general, in any chemical reaction, the amount of product formed is always less than the calculated amount due to reversibility in the chemical reaction. Therefore, yield of a chemical reaction (Y) comes into picture and is given by :

$$\text{The percentage yield of product} = \frac{\text{actual yield}}{\text{the theoretical maximum yield}} \times 100$$

Ex.22 In a certain operation 358 g of $TiCl_4$ is reacted with 96 g of Mg. Calculate % yield of Ti if 32 g of Ti is actually obtained [At. wt. Ti = 48, Mg = 24]

(A) 35.38 % (B) 66.6 % (C) 100 % (D) 60 %

Ans. (A)

Sol.

	$TiCl_4$ +	$2Mg$ $\longrightarrow$	Ti +	$2MgCl_2$
Initial mole	$\frac{358}{190} = 1.88$	$\frac{96}{24} = 4$		
final mole	0	$4 - 2 \times 1.88$	1.88	2×1.88

wt of Ti obtained $= \frac{358}{190} \times 48$

$$\% \text{ yield} = \frac{32 \times 100}{\frac{358 \times 48}{190}} = 35.38 \%$$

Ex.23 0.05 mole of $LiAlH_4$ in ether solution was placed in a flask containing 74g (1 mole) of t-butyl alcohol. The product $LiAlHC_{12}H_{27}O_3$ weighed 12.7 g. If Li atoms are conserved, the percentage yield is : (Li = 7, Al = 27, H = 1, C = 12, O = 16).

(A) 25% (B) 75% (C) 100% (D) 15%

Ans. (C)

Sol. $Li\,AlH_4$ + t-butyl alcohol $\xrightarrow{\text{Ether}}$ $LiAlH\,C_{12}H_{27}O_3$ (M.W. = 254)

0.05 mole 12.7 gram

$$= \frac{12.7}{254} = 0.05 \text{ mole}$$

Li atom remain conserved so

No. of mole of $LiAlH_4$ = No. of mole of $LiAlHC_{12}H_{27}O_3$

So No. of mole of $LiAlHC_{12}H_{27}O_3$ = 0.05

$$\%\ \text{yield} = \frac{0.05}{0.05} \times 100 = 100\%$$

4.5 PERCENTAGE PURITY:

Ex.24 How much marble of 90.5 % purity would be required to prepare 10 litres of CO_2 at 1 atm ,0 °Cwhen the marble is acted upon by dilute HCl ?

Ans. 49.326 g

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

100 g 22.4litre

22.4 L of CO_2 at STP will be obtained from 100 g of $CaCO_3$

$\therefore$ 10 L of CO_2 will be obtained from pure $CaCO_3 = \dfrac{100}{22.4} \times 10 = 44.64$ g

$\therefore$ Impure marble required $= \dfrac{100}{90.5} \times 44.64 = 49.326$ g

4.6 SEQUENTIAL REACTIONS:

This reaction is defined as that reaction which proceeds from reactants to final products through one or more intermediate stages. The overall reaction is a result of several successive or consecutive steps.

Example: $A \rightarrow B \rightarrow C$

Ex.25 Minimum amount of Ag_2CO_3 (s) required to produce sufficient oxygen for the complete combustion of C_2H_2 which produces 11.2 L of CO_2 at 1 atm and 273K after combustion is: [Ag = 108]

$$Ag_2CO_3\,(s) \longrightarrow 2Ag\,(s) + CO_2\,(g) + 1/2\,O_2\,(g)$$

$$C_2H_2 + 5/2\ O_2 \longrightarrow 2CO_2 + H_2O$$

Ans. 345 g

Sol. $Ag_2CO_3\,(s) \longrightarrow 2Ag\,(s) + CO_2\,(g) + 1/2\,O_2\,(g)$

$C_2H_2 + 5/2\ O_2 \longrightarrow 2CO_2 + H_2O$

By Stoichiometry of reaction

Moles of CO_2 formed $= \frac{11.2}{22.4} = \frac{1}{2}$

Moles of O_2 required $= \frac{5}{4} \times \frac{1}{2} = \frac{5}{8}$

Moles of Ag_2CO_3 required $= 2 \times \frac{5}{8} = \frac{5}{4}$

Mass of Ag_2CO_3 required $= \frac{5}{4} \times 276 = 345$ g

Ex.26 NX is produced by the following step of reactions

$M + X_2 \longrightarrow M X_2$

$3MX_2 + X_2 \longrightarrow M_3X_8$

$M_3\,X_8 + N_2CO_3 \longrightarrow NX + CO_2 + M_3O_4$

How much M (metal) is consumed to produce 206 g of NX.

(Take at wt of M = 56, N=23, X = 80)

(A) 42 g (B) 56 g (C) 52g (D) 64 g

Ans. (A)

Sol. $M + X_2 \longrightarrow MX_2$

$MX_2 + X_2 \longrightarrow M_3X_8$

$M_3X_8 + Na_2CO_3 \longrightarrow NX + CO_2 + M_3O_4$

mole of NX $= \frac{206}{103} = 2$

POAC for X Atom :

No. of X atom in M_3X_8 = No. of X Atom in NX

8 [No. of mole of M_3X_8] = 1 [No. of mole of NX]

No. of mole of M_3X_8 $= \left[\frac{2}{8}\right] = \frac{1}{4}$ mole

Now POAC for M Atom

3 [No. of mole of M_3X_8] = 1 × [No. of Mole of M]

$\therefore$ $3 \times \frac{1}{4}$ = No. of mole of M

weight of M atom $= \frac{3}{4} \times 56 = 42$ gram

Ex.27 The following process has been used to obtain iodine from oil-field brines in California.

$$NaI + AgNO_3 \longrightarrow AgI + NaNO_3 \ ;$$
$$2AgI + Fe \longrightarrow FeI_2 + 2Ag$$
$$2FeI_2 + 3Cl_2 \longrightarrow 2FeCl_3 + 2I_2$$

How many grams of $AgNO_3$ are required in the first step for every 254 kg I_2 produced in the third step.

(A) 340 kg (B) 85 kg (C) 68 kg (D) 380 kg

Ans. (A)

Sol. Balanced equation :

$$NaI + AgNO_3 \longrightarrow AgI + NaNO_3 \quad (1)$$
$$2AgI + Fe \longrightarrow FeI_2 + 2Ag \quad (2)$$
$$2FeI_2 + 3Cl_2 \longrightarrow 2FeCl_3 + 2I_2 \quad (3)$$

From (3)

$$\frac{\text{mole of } I_2}{2} = \frac{\text{mole of } FeI_2}{2}$$

$$\frac{\text{mole of } FeI_2}{1} = \frac{\text{mole of } AgI}{2}$$

$$\frac{\text{mole of } AgI}{1} = \frac{\text{mole of } AgNO_3}{1}$$

$\therefore$ mole of I_2 = (mole of FeI_2)

$$= \left(\frac{\text{mole of } AgI}{2}\right) = \left(\frac{\text{mole of } AgNO_3}{2}\right)$$

$$\frac{254\times10^3}{254} = \frac{\text{mole of } AgNO_3}{2}$$

$$2 \times 10^3 = \text{mole of } AgNO_3 = \frac{\text{mass of } AgNO_3}{\text{molar mass of } AgNO_3}$$

mass of $AgNO_3$ = $170 \times (2 \times 10^3)$ g = 340×10^3 g = 340 kg.

4.7 PARALLEL REACTIONS:

The reactions in which a substance reacts or decomposes in more than one way are called parallel or side reactions.

Example: $A \longrightarrow B$

$A \longrightarrow C$

Ex.28 Find out moles of CO_2 & CO produced by combustion of 2 mol carbon with 1.25 O_2 leaving number residue:

Ans. CO_2 = 0.5 mol, CO_2 = 1.5 mol

Sol.

$$C + O2 \longrightarrow CO_2$$
$$x \quad x \qquad\qquad x$$

$$C + \frac{1}{2} O_2 \longrightarrow CO$$
$$2–x \quad \frac{2-x}{2} \qquad 2–x$$

$$x + 1 – \frac{x}{2} = 1.25$$

$$\frac{x}{2} = \frac{125}{100}$$

x = 0.5 mol, CO_2 = 0.5 mol, CO_2 = 1.5 mol

4.8 MIXTURE ANALYSIS:

The analysis of a chemical reaction is generally carried out in the form of mass of reacting species taking part in a given reaction **(gravimetric analysis)** or in terms of concentrations of reacting species taking part in a given reaction **(volumetric analysis).** In Gravimetric Analysis, we generally analyse reactions such as : decomposition of compounds under heat to produce a residue and a gas, or displacement reactions, action of acids on metals, or simple balanced chemical equations involving Weight (solid) – Volume (gas) relationships. In Volumetric Analysis, we generally analyse Neutralisation and Redox Titrations involving aqueous solutions in general.

(i) Except Li carbonates of all the alkali metals are thermally stable and does not decompose on heating. $Li_2CO_3 \xrightarrow{\Delta} Li_2O + CO_2$

$$M_2CO_3 \xrightarrow{\Delta} \text{No reaction}$$

(M = Na, K, Rb, Cs)

(ii) All the carbonates of alkaline earth metals are thermally unstable and decompose on heating as follow.

$$MCO_3 \xrightarrow{\Delta} MO + CO_2$$

(iii) Bicarbonates of both alkali metals and alkaline earth metals are decomposed at relatively low temperature as follow.

$$2MHCO_3 \xrightarrow{\Delta} M_2CO_3 + H_2O + CO_2$$

$$M(HCO_3)_2 \xrightarrow{\Delta} MCO_3 + CO_2 + H_2O$$

Ex.29 A sample of 3 g containing Na_2CO_3 and $NaHCO_3$ loses 0.248 g when heated to 300°C, the temperature at which $NaHCO_3$ decomposes to Na_2CO_3, CO_2 and H_2O. What is the percentage of Na_2CO_3 in the given mixture?

Ans. 77.48%

Sol. The loss in weight is due to removal of CO_2 and H_2O which escape out on heating.

wt. of Na_2CO_3 in the product = 3.00 – 0.248 = 2.752 g

Let wt. of Na_2CO_3 in the mixture be x g

$\therefore$ wt. of $NaHCO_3$ = (3.00 – x) g

Since Na_2CO_3 in the products contains x g of unchanged reactant Na_2CO_3 and rest produced from $NaHCO_3$.

The wt. of Na_2CO_3 produced by $NaHCO_3$ = (2.752 – x)g

$NaHCO_3 \longrightarrow Na_2CO_3 + (H_2O + CO_2)\uparrow$

(3.0 – x) (2.752 – x)

Applying POAC for Na atom

$$1 \times \text{moles of } NaHCO_3 = 2 \times \text{moles of } Na_2CO_3 \Rightarrow \frac{(3-x)}{84} = 2x\frac{(2.752-x)}{106}$$

$\therefore$ x = 2.3244 g

$\therefore$ % of $Na_2CP_3 = \frac{2.3244}{3} \times 100 = 77.48\%$

Ex.30 10 g of a sample of a mixture of $CaCl_2$ and NaCl is treated to precipitate all the calcium as $CaCO_3$. This Ca CO_3 is heated to convert all the Ca to CaO and the final mass of CaO is 1.62 g. The percent by mass of $CaCl_2$ in the original mixture is.

(A) 32.1 % (B) 16.2 % (C) 21.8 % (D) 11.0 %

Ans. (A)

Sol. $CaCl_2$ + NaCl = 10 g

Let weight of $CaCl_2$ = x g

$CaCl \rightarrow CaCO_3 \rightarrow CaO$

1 mol 1 mol 1 mol

$\frac{x}{111}$ mol $\frac{x}{111}$ mol $\frac{x}{111}$ mol

Mole of CaO = $\frac{1.62}{56}$

$\therefore \frac{x}{111} = \frac{1.62}{56}$

x = 3.21 g

% of $CaCl_2 = \frac{3.21}{10} \times 100 = 32.1\ \%$

Do yourself-4:

1. 3.0 g an impure sample of sodium sulphate dissolved in water was treated with excess of barium chloride solution when 1.74 g of $BaSO_4$ was obtained as dry precipitate. Calculate the percentage purity of sample.

2. If the percentage yield of given reaction is 30%, how many total moles of the gases will be produced, if 8 moles of $NaNO_3$ are taken initially :

$NaNO_3(s) \longrightarrow Na_2O(s) + N_2(g) + O_2(g)$ (unbalanced)

(A) 4.2 mole (B) 2.4 mole (C) 4.8 mole (D) 2.1 mole

3. A 5 g mixture of SO_2 and O_2 gases is reacted to form SO_3 gas. What should be the mass ratio of SO_2 and O_2 gases in mixture to obtain maximum amount of SO_3gas :

(A) 4 : 1 (B) 3 : 2 (C) 2 : 3 (D) 1 : 4

4. 25.4 g of iodine and 14.2g of chlorine are made to react completely to yield a mixture of ICl and ICl_3. Calculate the number of moles of ICl and ICl_3 formed.

(A) 0.1 mole, 0.1 mole (B) 0.1 mole, 0.2 mole

(C) 0.5 mole, 0.5 mole (D) 0.2 mole, 0.2 mole

5. When 1 mole of A reacts with $\frac{1}{2}$ mole of B_2 ($A + \frac{1}{2}B_2 \longrightarrow AB$), 100 Kcal heat is liberated and when 1 mole of A reacted with 2 mole of B_2 ($A + 2B_2 \longrightarrow AB_4$), 200 Kcal heat is liberated. When 1 mole of A is completely reacted with excess, of B_2 to form AB as well as AB_4, 140 Kcal heat is liberated calculate the mole of B_2 used.

[Write your answer as number of mole of B_2 used × 10]

6. A solid mixture weighing 5.00 g containing lead nitrate and sodium nitrate was heated below 600°C until the mass of the residue was constant. If the loss of mass is 30 %, find the mass of lead nitrate and sodium nitrate in mixture.

$$2Pb(NO_3)_2 \xrightarrow{\Delta} 2PbO + 4NO_2\uparrow + O_2\uparrow$$

$$2NaNO_3 \xrightarrow{\Delta} 2NaNO_2 + O_2\uparrow$$

(At. wt. of Pb = 207, Na = 23, N = 14, O = 16)

5. DENSITY:

It is of two type.

1 . Absolute density 2 . Relative density

(a) For liquid and solids

$$\text{Absolute density} = \frac{\text{mass}}{\text{volume}}$$

$$\text{Relative density or specific gravity} = \frac{\text{density of the substance}}{\text{density of water at } 4^\circ C}$$

(b) For gasses:

Absolute density (mass / volume) = $\frac{PM}{RT}$

where P is pressure of gas, M = mol. wt. of gas, R is the gas constant, T is the temperature.

Relative density andVapour density:

Vapour density is defined as the density of the gas with respect to hydrogen gas at the same temperature and pressure.

$$\text{Vapour density} = \frac{d_{gas}}{d_{H_2}} = \frac{PM_{gas}/RT}{PM_{H_2}/RT}$$

$$\text{V.D.} = \frac{M_{gas}}{M_{H_2}} = \frac{M_{gas}}{2} \Rightarrow \boxed{M_{gas} = 2\text{V.D.}}$$

Ex.31 Find the relative density of SO_3 gas with respect to methane :

(A) 8 (B) 3.5 (C) 2.5 (D) 5

Ans. (D)

Sol. R.D. $= \frac{M_{SO_3}}{M_{CH_4}} = \frac{80}{16} = 5.$

Ex.32 The atomic mass of a metal is 27 u. If its valency is 3, the vapour density of the volatile metal chloride will be:

(A) 66.75 (B) 321 (C) 267 (D) 80.25

Ans. (A)

Sol. Element must be Al

Hence, volatile chloride will be $AlCl_3$ so V.D. $= \frac{M_{AlCl_3}}{2} = \frac{133.5}{2} = 66.75$

Ex.33 The density of water at 4°C is 1×10^3 kg m^{-3}. Assuming no empty space to be present between water molecules, the volume occupied by one molecule of water is approximately :

(A) 3×10^{-23} mL (B) 6×10^{-23} mL (C) 3×10^{-22} mL (D) 6×10^{-22} mL

Ans. (A)

Sol. 1×10^3 kg/m^3 = 1 g/mL. [Since, 1m^3 = 10^6 cm^3 = 10^6 mL].

= 1 gm/cc

6.022×10^{23} H_2O molecule weigh …18 g

1 H_2O molecule weigh .. $\frac{18}{6.022 \times 10^{23}}$ g = 3×10^{-23} g

$d = \frac{\text{mass}}{\text{volume}}$, So, volume $= \frac{3 \times 10^{-23}\text{ g}}{1(\text{g/mL})}$ = 3×10^{-23}mL.

6. AVERAGE/ MEAN ATOMIC MASS :

The weighted average of the isotopic masses of the element's naturally occuring isotopes.

Mathematically, average atomic mass of X (A_x) = $\dfrac{a_1x_1 + a_2x_2 + ... + a_nx_n}{100}$

Where :

a_1, a_2, a_3 .... atomic mass of isotopes.

and x_1, x_2, x_3 .... mole % of isotopes.

Ex.34 Naturally occurring chlorine is 75.53% Cl^{35} which has an atomic mass of 34.969 amu and 24.47% Cl^{37} which has a mass of 36.966 amu. Calculate the average atomic mass of chlorine -

(A) 35.5 amu (B) 36.5 amu (C) 71 amu (D) 72 amu

Sol. (A) Average atomic mass =

(% of I isotope × Its atoms mass)+(% II isotope × its atomic mass)/ 100

$= \dfrac{75.53 \times 34.969 + 24.47 \times 36.96}{100}$

= 35.5 amu.

6.1 AVERAGE MOLAR MASS OR AVERAGE GRAM MOLECULAR MASS:

The average molar mass of the different substance present in the container $= \dfrac{n_1M_1 + n_2M_2 + ...n_nM_n}{n_1 + n_2 + ...n_n}$

Where :

M_1, M_2, M_3 .... are molar masses.

n_1, n_2, n_3 .... moles of substances.

Average molecule wt. = $\dfrac{\Sigma n_i M_i}{\Sigma n_i}$ where n_i = no. of moles of compound, m_i = molecular mass of compound

Ex.35 The molar composition of polluted air is as follows :

Gas	mole percentage composition
Oxygen	16%
Nitrogen	80%
Carbon dioxide	03%
Sulphurdioxide	01%

What is the average molecular weight of the given polluted air ?

Ans. 29.48

Sol. $M_{avg} = \dfrac{16 \text{ x } 32 + 80 \text{ x } 28 + 44 \text{ x } 3 + 64 \text{ x } 1}{100} = \dfrac{512 + 2240 + 132 + 64}{100} = \dfrac{2948}{100} = 29.48$

6.2 DEGREE OF DISSOCIATION (α):

Degree of dissociation represents the fraction of one mole dissociated into the products. (Defined for one mole of substance)

So, α = no. of moles dissociated / initial no. of moles taken

= fraction of moles dissociated out of 1 mole.

Note : % dissociation = α x 100

Suppose 5 moles of PCl_5 is taken and if 2 moles of PCl_5 dissociated then $\alpha = \frac{2}{5} = 0.4$

6.3 RELATIONSHIP BETWEEN AVERAGE MOLAR MASS& DEGREE OF DISSOCIATION (α):

Let a gas A_n dissociates to give n moles of A as follows-

	$A_n(g)$ $\rightleftharpoons$	$nA(g)$	
$t = 0$	a	0	
$t = t_{eq}$	$a - x$	nx	$\alpha = \frac{x}{a} \Rightarrow \quad x = a\alpha.$
	$a - a\alpha = a(1-\alpha)$	$n a \alpha$	

Total no. of moles = $a - a\alpha + na\alpha$

$= [1 + (n-1)\alpha]\, a$

Average molecular weight of mixture(g)= $\dfrac{\text{molecular weight of } A_n(g)}{\text{total no. of moles at equilibrium}}$

$$= \frac{a.M_{th}}{a(1+(n-1)\alpha)}$$

$$M_{avg} = \frac{M_{th}}{[1+(n-1)\alpha]}$$

where M_{th} = theoritical molecular weight (n = atomicity)

$$M_{mixture} = \frac{M_{A_n}}{[1+(n-1)\alpha]},\quad M_{A_n} = \text{Molar mass of gas } A_n$$

Vapour density (V.D). : Density of the gas divided by density of hydrogen under same temperature & pressure is called vapour density.

D = vapour density without dissociation = $\dfrac{M_{A_n}}{2}$

d = vapour density of mixture = averagevapour density

$$\frac{D}{d} = 1 + (n-1)\alpha$$

$$\alpha = \frac{D-d}{(n-1)\times d} = \frac{M_T - M_o}{(n-1)M_0}$$

Ex.36 NH_3 decomposes into N_2 & H_2. If average molar mass of reaction mixture is 10 then, find α ?

Ans. 0.7

Sol.

$$NH_3 \longrightarrow \frac{1}{2}N_2 + \frac{3}{2}H_2$$

$$n_1 \quad 1 \qquad 0 \qquad 0$$

$$1-\alpha \qquad \frac{\alpha}{2} \qquad \frac{3\alpha}{2}$$

$$10 = \frac{17}{1-\alpha+\frac{\alpha}{2}+\frac{3\alpha}{2}}$$

$$10 = \frac{17}{1+\alpha}$$

$1 + \alpha = 1.7$

$\alpha = 0.7$

7. PERCENTAGE COMPOSITION AND MOLECULAR FORMULA :

Here we are going to find out the percentage of each element in the compound by knowing the molecular formula of compound.
We known that according to law of definite proportion any sample of a pure compound always possess constant ratio with their combining elements.

- **Example:**

Every molecule of ammonia always has formula NH_3 irrespective of method of preparation or sources. i.e. 1 mole of ammonia always contains 1 mol of N and 3 mole of H. In other wards 17 g of NH_3 always contains 14 g of N and 3 g of H. Now find out % of each element in the compound.

Mass % of N in NH_3 = $\frac{\text{Mass of N in 1 mol } NH_3}{\text{Mass of 1 mol of } NH_3}$ 100 = $\frac{14g}{17}$ 100 = 82.35 %

Mass % of H in NH_3 = $\frac{\text{Mass of H in 1 mol } NH_3}{\text{Mass of 1 mol of } NH_3}$ 100 = $\frac{3}{17}$ 100 = 17.65%

7.1. EMPIRICAL AND MOLECULAR FORMULA:

We have just seen that knowing the molecular formula of the compound we can calculate percentage composition of the elements. Conversely if we know the percentage composition of the elements initially, we can calculate the relative number of atoms of each element in the molecules of the compound. This gives as the empirical formula of the compound. Further if the molecular mass is known then the molecular formula can be easily determined.
Thus, the empirical formula of a compound is a chemical formula showing the relative number of atoms in the simplest ratio, the molecular formula gives the actual number of atoms of eachelement in a molecule.

Empirical formula: An empirical formula represents the simple whole number ratio of various atoms present in a compound,

Molecular formula: whereas, the molecular formula shows the exact number of different types of atoms present in a molecule of a compound

The molecular formula is generally an integral multiple of the empirical formula.

That is : $\boxed{\text{molecular formula} = \text{empirical formula} \times \text{n}}$

$$\text{where n} = \frac{\text{molecular formula mass}}{\text{emprirical formula mass}}$$

Ex.37 An organic substance containing carbon, hydrogen and oxygen gave the following percentage composition.

C = 40.687 % ; H = 5.085 % and O = 54.228 %

The molecular weight of the compound is 118. Calculate the molecular formula of the compound.

Ans. $C_4H_6O_4$

Sol. **Step -1**

To calculate the empirical formula of the compound.

Element	Symbol	Percentage of element	At. mass of element	Relative no. of atoms = $\frac{\text{Percentage}}{\text{At.mass}}$	Simplest Atomic ratio	Simplest whole no. atomic ratio
Carbon	C	40.687	12	$\frac{40.687}{12} = 3.390$	$\frac{3.390}{3.389} = 1$	2
Hydrogen	H	5.085	1	$\frac{5.085}{1} = 5.035$	$\frac{5.085}{3.389} = 1.5$	3
Oxygen	O	54.228	16	$\frac{54.228}{16} = 3.389$	$\frac{3.389}{3.389} = 1$	2

- **Step - 2**

  To calculate the empirical formula mass.

  The empirical formula of the compound is $C_2H_3O_2$.

  $\therefore$ Empirical formula mass

  $= (2 \times 12) + (3 \times 1) + (2 \times 16) = 59.$

- **Step - 3**

  To calculate the value of 'n'

  $$\text{n} = \frac{\text{molecular mass}}{\text{Empirical formula nass}} = \frac{118}{59} = 2$$

- **Step - 4**

  To calculate the molecular formula of the salt

  Molecular formula $= \text{n} \times (\text{Empirical formula})$

  $= 2 \times C_2H_3O_2 = C_4H_6O_4$

  Thus the molecular formula is $C_4H_6O_4$.

Ex.38 Chlorophyll the green colouring material of plants contains 3.68 % of magnesium by mass. Calculate the number of magnesium atom in 5.00 g of the complex.

Sol. Mass of magnesium in5.0 g of complex = $\frac{3.68}{100}$ 5.00 = 0.184 g

Atomic mass of magnesium = 24

24 g of magnesium contain = 6.023×10^{23} atoms

0.184 g of magnesium would contain = $\frac{6.023\times10^{23}}{24}$ 0.184 = 4.617 × 1021 atom

Therefore, 5.00 g of the given complex would contain 4.617×10^{21} atoms of magnesium.

Ex.39 A sample of $CaCO_3$ has Ca = 40%, C = 12% and O = 48% by mass. If the law of constant proportions is true, then the mass of Ca in 5 g of $CaCO_3$ obtained from another source will be:

(A) 0.2 g (B) 2 g (C) 0.6 g (D) Cannot be determined

Ans. (B)

Sol. Mass of Ca = $5 \times \frac{40}{100}$ = 2g.

8. EXPERIMENTAL METHODS TO DETERMINE ATOMIC & MOLECULAR MASSES

8.1 For determination of atomic mass :

(*a*) Dulong's & Pettit' slaw :

In case of metals, it is observed that product of atomic weight and specific heat capacity is constant.

The equation connecting the two parameters was given by Dulong's and Petit's Law.

Atomic weight of metal × specific heat capacity (cal/gm°C) = 6.4.

In should be remembered that this law is an empirical observation and this gives an approximate value of atomic weight. Also this law can be applied only to metals at high temperature conditions only.

8.2 Experimental methods for molecular mass determination.

(a) Victor Meyer's Method

(b) Silver Salt Method

(c) Chloroplatinate Salt Method

(a) Victor Meyer's Method: (Applicable for volatile substance)

A known mass of the volatile substance taken in the Hoffmann's bottle and is vapourised by throwing the Hoffmann's bottle into the Vector Meyer's tube. The vapour displace an equal volume of the moist air. Which vapours is measured at the room temperature and atmospheric pressure. The barometric pressure and the room temperature is recorded. Following diagram gives the experimental set-up for the Victor-Meyer's process.

Calculation involved

Let the mass of the substance taken by = Wg

Volume of moist vapours collected = $V cm^3$

Room temperature = TK

Barometric pressure = P mm

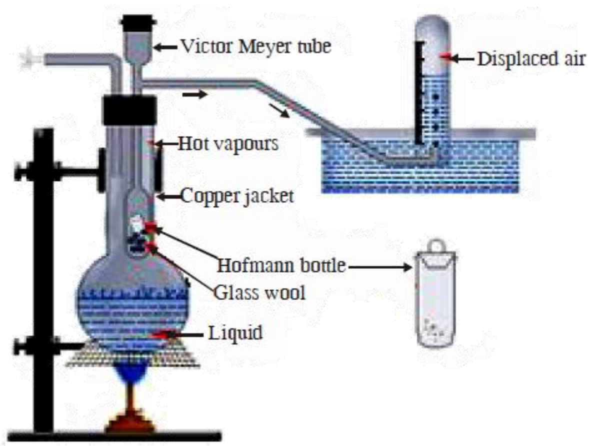
Aqueous tension at TK = p mm

Pressure of dry vapour = (P – p) mm

Calculation of molecular mass (M)

$$\frac{(P-p)}{760}\times\frac{V}{1000} = \frac{w}{M}\times RT$$

$$\Rightarrow \quad M = \frac{w\times RT\times 760\times 1000}{(P-p)\times V}$$



(b) Silver salt Method: (A used for organic acids)

A known mass of the acid is dissolved in water followed by the subsequent addition of silver nitrate solution till the precipitation of silver salt is complete. The precipitate is separated, dried, weighed

$$\text{Organic acid}\xrightarrow{AgNO_3}\text{Silver salt}\xrightarrow{\text{Ignite}}Ag$$

and ignited till decomposition is complete. The residue of pure silver left behind is weighed. Calculations involved

Let the mass of the silver salt formed = W g

The mass of Ag formed = x g

Let us understand to calculations by considering the monobasic acid MX.

$$\underset{\text{Organic acid}}{HA}\xrightarrow{AgNO_3}\underset{\text{Silver salt (Wg)}}{AgA}\xrightarrow{\text{Tgnite}}\underset{\text{Silver (xg)}}{Ag}$$

Mass of the salt that gives x gm of Ag = W g

Mass of the salt gives 108g (1g-atom) of Ag = $\frac{108W}{x}$g

Molar mass of salt = $\frac{108W}{x}$g

Molar mass of acid = (Molar mass of salt) – (Atomic mass of Ag) + (Atomic mass of H)

$$= \frac{108W}{x}-108+1 = \left(\frac{108W}{x}-107\right)g\,mol^{-1}$$

For polybasic acid of the type H_nX (n is basicity)

$$\underset{\text{Organic acid}}{H_nA} \xrightarrow{AgNO_3} \underset{\text{Silver salt (Wg)}}{Ag_nA} \xrightarrow{\text{Tgnite}} \underset{\text{Silver (xg)}}{nAg}$$

Mass of the silver that gives x g of Ag = W g

Mass of the silver that gives (108n g) of Ag = $\dfrac{108nW}{x}$ g

Molar mass of salt = $\dfrac{108 \times nW}{x}$ g

Molar mass of acid = (molar mass of salt) = $\dfrac{108 \times nW}{x} - n \times 108 - n \times 1$

$= n\left(\dfrac{108W}{x} - 107\right) g\,mol^{-1}$

(c) Platinic chloride Method : (Applicable for finding the molecular masses of organic bases).

A known mass of organic base is allowed to react with chloroplatinic acid (H_2PtCl_6) in conc. HCl to form insoluble platinic chloride. The precipitate of platinic chloride is separated, dried, weighed and subsequently ignited till decomposition is complete. The residue left is platinum which is again weighed. The molecular mass is then calculated by knowing the mass of the platinic chloride salt and that of platinum left.

If B represents the molecule of monoacidic organic base, then the formula of platinic chloride salt is

$B_2H_2PtCl_6$.

$$\underset{\text{Organic base}}{B} \xrightarrow[\text{conc.HCl}]{H_2PtCl_6} \underset{\text{Platinic chloride salt (Wg)}}{B_2H_2PtCl_6} \xrightarrow{\text{Ignite}} \underset{(xg)}{Pt}$$

Let the mass of platinic chloride salt = W g, The mass of the platinum residue left = x g

It may be noted that salt formed with diacidic base would be $B_2\,(H_2PtCl_6)_2$

With triacidic base it would be $B_2\,(H_2PtCl_6)_3$ and with polyacidic base would be $B_2(H_2PtCl_6)_n$.

Mass of salt which gives 195 g (1 g–atom) of Pt $\dfrac{W \times 195}{x}$ g

Molar mass of salt = $\dfrac{W \times 195}{x} g\,mol^{-1}$

Now from the formula $B_2(H_2PtCl_6)$

Molar mass of salt = (2 × molar mass of base) + (Molar mass of H_2PtCl_6)

Molar mass of base = $\dfrac{1}{2}$ (molar mass of salt – Molar mass of H_2PtCl_6)

$$= \frac{1}{2}\left(\frac{W \times 195 \times n}{x} - n \times 410\right) = \frac{n}{2}\left(\frac{w \times 195}{x} - 410\right) g\,mol^{-1}$$

Do yourself-5:

1. 120 g Mg is burnt in air to give a mixture of MgO and Mg_3N_2. The mixture is now dissolved in HCl to form $MgCl_2$ and NH_4Cl. If 107 g NH_4Cl is produced, then determine the moles of $MgCl_2$ formed:

(A) 2.5 (B) 4 (C) 2 (D) 5

2. Penicillin V was treated chemically to convert the sulphur present to barium sulphate, $BaSO_4$. A 9.6 mg sample of penicillin V gave 4.66 mg $BaSO_4$. The percentage of sulphur in Penicillin V is x %. If there is one sulphur atom in the molecule, the molecular weight of Pencillin V is y amu.

Report your answer as y/x.

3. From the following reaction sequence :

$$Cl_2 + 2KOH \longrightarrow KCl + KClO + H_2O$$
$$3KClO \longrightarrow 2KCl + KClO_3$$
$$4KClO_3 \longrightarrow 3KClO_4 + KCl$$

Calculate the mass of chlorine needed to produce 138.5 g of $KClO_4$:

(A) 142 g (B) 284 g (C) 432 g (D) None of these

4. The density of air at STP is 0.0013 g mL^{-1}. Its vapour density is :

(A) 0.015 (B) 15 (C) 1.5 (D) Data insufficient

5. $SO_3(g) \rightleftharpoons SO_2(g) + \frac{1}{2} O_2(g)$

If observed vapour density of mixture at equilibrium is 35 then find out value of α:

(A) 0.28 (B) 0.38 (C) 0.48 (D) 0.58

6. A sample of a compound contains 9.75 g Zn, 9×10^{22} atoms of Cr and 0.6 gram-atoms of O. What is empirical formula of compound? (Atomic Mass Zn = 65)

(A)$ZnCrO_4$ (B)$ZnCr_2O_4$ (C)Zn_2CrO_4 (D) None of these

7. An organic compound on analysis was found to contain 0.032% of sulphur by mass. The molecular mass of the compound, if it's one molecule contains two sulphur atoms, is :

(A) 100000 u (B) 10000 u (C) 20000 u (D) 200000 u

8. In an organic compound of molar mass108 g mol^{-1} C, H and N atoms are present in 9 : 1 : 3.5 by weight. Molecular formula can be :

(A) $C_6H_8N_2$ (B) $C_7H_{10}N$ (C) $C_5H_6N_3$ (D) $C_4H_{18}N_3$

9. At 100° C and 1 atmp , if the density of liquid water is 1.0 g cm^{-3} and that of water vapour is 0.0006 g cm^{-3} , then the volume occupied by water molecules in 1 L of steam at that temperature is :

(A) 6 cm^3 (B) 60 cm^3 (C) 0.6 cm^3 (D) 0.06 cm^3

ANSWER KEY

DO YOURSELF

Do yourself-1:

1. N_A
2. (C)
3. (i) $H = 4N_A$, $S = 2N_A$, $O = 8N_A$ atoms (ii) H = 4 atoms, S = 2 atoms, O = 8 atoms.
(iii) $H = 10N_A$, $S = 10N_A$, $O = 40\ N_A$ atoms (iv) H = 6 atoms, S = 6 atoms, O = 18 atoms.
4. 1.88×10^{22} **5.** (C) **6.** (A) **7.** (B)

Do yourself-2:

1. (A) **2.** 2.16 g **3.** (C) **4.** (C) **5.** (C)

Do yourself-3:

1. (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.
2. (A) **3.** (A) **4.** (A) **5.** (C)

Do yourself-4:

1. 35.33 % **2.** (D) **3.** (A) **4.** (A) **5.** 11 **6.** 0.95 g

Do yourself-5:

1. (D) **2.** (72) **3.** (B) **4.** (B) **5.** (A) **6.** (A)
7. (D) **8.** **(A)** **9.** (C)

EXERCISE (S- I) C XI M1 Pg14~

PROBLEMS RELATED WITH DIFFERENT TYPES OF ATOMIC MASSES & BASIC CONCEPT OF MOLE

14 **1.** How much time (in seconds) would it take to distribute one Avogadro number of wheat grains if 10^{10} grains are distributed each second ?

14 **2.** What is the mass of one ^{12}C atom in gram ?

14 **3.** Calculate the weight of 12.046×10^{23} atoms of carbon.

4. Find :
14 (i) No. of moles of Cu atom in 10^{20} atoms of Cu.
14 (ii) Mass of 200 atoms of $^{16}_{8}O$ in amu
14 (iii) Mass of 100 atoms of $^{14}_{7}N$ in gm.
15 (iv) No. of molecules & atoms in 54 gm H_2O.
15 (v) No. of atoms in 88 gm CO_2.

15 **5.** Calculate mass of O atoms in 6 gm CH_3COOH ?

16 **6.** Calculate mass of water present in 499 gm $CuSO_4.5H_2O$?
(Atomic mass – Cu = 63.5, S = 32, O = 16, H = 1)

16 **7.** What mass of $Na_2SO_4.7H_2O$ contains exactly 6.023×10^{22} atoms of oxygen ?

17 **8.** Find the total number of nucleons present in 12 g of ^{12}C atoms.

17 **9.** Calculate the number of electrons, protons and neutrons in 1 mole of $^{16}O^{-2}$ ions.

17 **10.** The density of liquid mercury is 13.6 g/cm^3. How many moles of mercury are there in 1 litre of the metal ? (Atomic mass of Hg = 200.)

18 **11.** A sample of ethane has the same mass as 10.0 million molecules of methane. How many C_2H_6 molecules does the sample contain ?

18 **12.** If, from 10 moles NH_3 and 5 moles of H_2SO_4 , all the H-atoms are removed in order to form H_2 gas, then find the number of H_2 molecules formed.

STOICHIOMETRY

19 **13.** Chlorine can be prepared by reacting HCl with MnO_2. The reaction is represented by the equation:

$$MnO_2(s) + 4HCl \longrightarrow Cl_2(g) + MnCl_{2(aq)} + 2H_2O(l)$$

Assuming the reaction goes to completion, what mass of HCl solution is needed to produce 142 g of Cl_2

19 **14.** Calculate the volume of O_2 needed for combustion of 1.2 kg of carbon at STP.
Reaction : $C + O_2 \xrightarrow{\Delta} CO_2$.

20 **15.** Methyl-t-butyl ether, $C_5H_{12}O$, is added to gasoline to promote cleaner burning. How many moles of oxygen gas, O_2 are required to burn 1.0 mol of this compound completely to form carbon dioxide and water ?

20, 21 **16.** Aluminum carbide (Al_4C_3) liberates methane on treatment with water : $Al_4C_4 + 12H_2O \longrightarrow 3CH_4 + 4Al(OH)_3$ Find mass of aluminum carbide required to produce 11.35 L of methane under STP conditions.

21 **17.** Calculate mass of phosphoric acid required to obtain 53.4g pyrophosphoric acid.
$2H_3PO_4 \rightarrow H_4P_2O_7 + H_2O$

22 **18.** Nitric acid is manufactured by the Ostwald process, in which nitrogen dioxide reacts with water.
$3\ NO_2\ (g) + H_2O\ (l) \rightarrow 2\ HNO_3\ (aq) + NO\ (g)$
How many grams of nitrogen dioxide are required in this reaction to produce 25.2 gm HNO_3 ?

19. Flourine reacts with uranium to produce uranium hexafluoride, UF_6, as represented by this equation
22 $U(s) + 3F_2(g) \rightarrow UF_6(g)$
How many fluorine molecules are required to produce 2.0 mg of uranium hexafluoride, UF_6, from an excess of uranium ? The molar mass of UF_6 is 352 gm/mol.

23 **20.** XeF_6 fluorinates I_2 to IF_7 and liberates Xenon(g). 3.5 mmol of XeF_6 can yield a maximum of_____ mmol of IF_7.

21. What total volume, in litre at 600°C and 1 atm, could be formed by the decomposition of 16 gm of
23 NH_4NO_3 ?
$$2\ NH_4NO_3 \rightarrow 2N_2 + O_2 + 4H_2O_{(g)}$$

LIMITING REACTANT

22. 50 g of $CaCO_3$ is allowed to react with 73.5 g of H_3PO_4. Calculate :
(i) Amount of $Ca_3(PO_4)_2$ formed (in moles)
[In class] (ii) Amount of unreacted reagent (in moles)

23. Reaction $4A + 2B + 3C \longrightarrow A_4B_2C_3$, is started from 2 moles of A, 1.2 moles of B & 1.44 moles of C. find number of moles of product formed.
[In class]

24. Potassium superoxide, KO_2, is used in rebreathing gas masks to generate oxygen :
[In class] $KO_2(s) + H_2O(l) \rightarrow KOH\ (s) + O_2\ (g)$
If a reaction vessel contains 0.158 mol KO_2 and 0.10 mol H_2O, how many moles of O_2 can be produced?

25. A chemist wants to prepare diborane by the reaction
$6\ LiH + 8BF_3 \longrightarrow 6Li\ BF_4 + B_2H_6$
[In class] If he starts with 2.0 moles each of LiH & BF_3. How many moles of B_2H_6 can be prepared.

26. Titanium, which is used to make air plane engines and frames, can be obtained from titanium tetrachloride, which in turn is obtained from titanium oxide by the following process :
$3\ TiO_2(s) + 4C\ (s) + 6Cl_2\ (g) \longrightarrow 3TiCl_4(g) + 2CO_2(g) + 2CO\ (g)$
[In class] A vessel contains 4.32 g TiO_2, 5.76 g C and; 7.1 g Cl_2, suppose the reaction goes to completion as written, how many gram of $TiCl_4$ can be produced ? (Ti = 48)

27. Carbon reacts with chlorine to form CCl_4. 36 gm of carbon was mixed with 142 g of Cl_2. Calculate mass of CCl_4 produced and the remaining mass of reactant.
[In class]

28. Sulphuric acid is produced when sulphur dioxide reacts with oxygen and water in the presence of a catalyst : $2SO_2(g) + O_2(g) + 2H_2O(l) \rightarrow 2H_2SO_4$. If 5.6 mol of SO_2 reacts with 4.8 mol of O_2 and a large excess of water, what is the maximum number of moles of H_2SO_4 that can be obtained ?
[In class]

PROBLEMS RELATED WITH MIXTURE

29. One gram of an alloy of aluminium and magnesium when heated with excess of dil. HCl forms magnesium chloride, aluminium chloride and hydrogen. The evolved hydrogen collected at 0°C has a volume of 1.12 litres at 1 atm pressure. Calculate the composition of (% by mass) of the alloy.
[In class]

30. A sample containing only $CaCO_3$ and $MgCO_3$ is ignited to CaO and MgO. The mixture of oxides produced weight exactly half as much as the original sample. Calculate the percentages of $CaCO_3$ and $MgCO_3$ (by mass) in the sample.
[In class]

31. Determine the percentage composition (by mass) of a mixture of anhydrous sodium carbonate and sodium bicarbonate from the following data:
wt. of the mixture taken = 2g
Loss in weight on heating = 0.11 gm.
[In class]

32. 92 g mixture of $CaCO_3$, and $MgCO_3$ heated strongly in an open vessel. After complete decomposition of the carbonates it was found that the weight of residue left behind is 48 g. Find the mass of $MgCO_3$ in grams in the mixture.
[In class]

33. When 4 gm of a mixture of $NaHCO_3$ and NaCl is heated, 0.66 gm CO_2 gas is evolved. Determine the percentage composition (by mass) of the original mixture.
[In class]

PERCENTAGE YIELD AND PERCENTAGE PURITY

34. 200 g impure $CaCO_3$ on heating gives 11.35 L CO_2 gas at STP. Find the percentage of calcium in the lime stone sample.
[In class]

35. A power company burns approximately 474 tons of coal per day to produce electricity. If the sulphur content of the coal is 1.30 % by weight, how many tons SO_2 are dumped into the atmosphere each day?
[In class]

36. Calculate the percent loss in weight after complete decomposition of a pure sample of potassium chlorate.
$KClO_3(s) \longrightarrow KCl(s) + O_2(g)$
[In class]

37. A sample of calcium carbonate is 80% pure, 25 gm of this sample is treated with excess of HCl.How much volume of CO_2 will be obtained at 1 atm & 273 K?
[In class]

38. Cyclohexanol is dehydrated to cyclohexene on heating with conc. H_2SO_4. If the yield of this reaction is 75%, how much cyclohexene will be obtained from 100 g of cyclohexanol ?
[In class]

$C_6H_{12}O \xrightarrow{con.H_2SO_4} C_6H_{10}$

39. If the yield of chloroform obtainable from acetone and bleaching powder is 75%. What is the weight of acetone required for producing 30 gm of chloroform ?

[In class]

$2CH_3COCH_3 + 6CaOCl_2 \rightarrow Ca(CH_3COO)_2 + 2CHCl_3 + 3CaCl_2 + 2Ca(OH)_2$

40. The percent yield for the following reaction carried out in carbon tetrachloride (CCl_4) solution is 80%

$$Br_2 + Cl_2 \longrightarrow 2BrCl$$

[In class]

(a) What amount of BrCI would be formed from the reaction of 0.025 mol Br_2 and 0.025 mol Cl_2?

(b) What amoumt of Br_2 is left unchanged?

SEQUENTIAL & PARALLEL REACTIONS

41. Sulphur trioxide may be prepared by the following two reactions :

$S_8 + 8O_2(g) \rightarrow 8SO_2(g)$

[In class]

$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$

How many grams of SO_3 will be produced from 1 mol of S_8?

42. $2PbS + 3O_2 \rightarrow 2PbO + 2SO_2$

[In class]

$3SO_2 + 2HNO_3 + 2H_2O \rightarrow 3H_2SO_4 + 2NO$

According to the above sequence of reactions, how much H_2SO_4 will 1075.5 gm of PbS produce?

43. Potassium superoxide, KO_2, is utilised in closed system breathing apparatus. Exhaled air contains CO_2 and H_2O, both of which are removed and the removal of water generates oxygen for breathing by the reaction

$4KO_2(s) + 2H_2O(l) \rightarrow 3O_2(g) + 4KOH(s)$

[In class]

The potassium hydroxide removes CO_2 from the apparatus by the reaction :

$KOH\ (s) + CO_2\ (g) \rightarrow KHCO_3(s)$

(a) What mass of KO_2 generates 20 gm of oxygen ?

(b) What mass of CO_2 can be removed from the apparatus by 100 gm of KO_2 ?

MISCELLANEOUS PROBLEM

44. In a determination of P an aqueous solution of NaH_2PO_4 is treated with a mixture of ammonium and magnesium ions to precipitate magnesium ammonium phosphate $Mg(NH_4)PO_4 . 6H_2O$. This is heated and decomposed to magnesium pyrophosphate, $Mg_2P_2O_7$ which is weighed. A solution of NaH_2PO_4 yielded 1.054 g of $Mg_2P_2O_7$. What weight of NaH_2PO_4 was present originally?

45. Calculate the amount of H_2SO_4 produced (in gm) when 40 ml H_2O (d = 0.9 gm/ml) reacts with 50 litre SO_3 at 1 atm. and 300 K, according to the following reaction ?

$H_2O + SO_3 \rightarrow H_2SO_4$

46. 0.80g of the chloroplatinate of a mono acid base on ignition gave 0.262g of ppt. Calculate the molecular weight of the base.

Pb-48

47. Calculate the atomic mass (average) of chlorine using the following data :

	% Natural Abundance	Molar Mass
^{35}Cl	75.77	34.9689
^{37}Cl	24.23	36.9659

Pb-48

48. Average atomic mass of Magnesium is 24.31 amu. This magnesium is composed of 79 mole % of ^{24}Mg and remaining 21 mole % of ^{25}Mg and ^{26}Mg. Calculate mole % of ^{26}Mg.

49. A moth repellent has the composition 49% C, 2.7% H and 48.3% Cl. Its molecular weight is 147 gm. Determine its molecular formula

50. Haemoglobin contains 0.25% iron by mass. The molecular mass of of Haemoglobin is 89600 then the number of iron atoms per molecule of Haemoglobin (Atomic mass of Fe = 56)

EXERCISE (S-II)

1. Sodium chlorate, $NaClO_3$, can be prepared by the following series of reactions:

$2KMnO_4 + 16\ HCl \rightarrow 2\ KCl + 2\ MnCl_2 + 8H_2O + 5\ Cl_2$

30-31 $6Cl_2 + 6\ Ca(OH)_2 \rightarrow Ca(ClO_3)_2 + 5\ CaCl_2 + 6H_2O$

$Ca(ClO_3)_2 + Na_2SO_4 \rightarrow CaSO_4 + 2\ NaClO_3$

What mass of $NaClO_3$ can be prepared from 100 ml of concentrated HCl (density 1.18 gm/ml and 36% by mass)? Assume all other substances are present in excess amounts.

2. Two substance P_4 & O_2 are allowed to react completely to form mixture of P_4O_6 & P_4O_{10} leaving none of the reactants. Using this information calculate the composition of final mixture when mentioned amount of P_4 & O_2 are taken.

$P_4 + 3O_2 \longrightarrow P_4O_6$

31-32 $P_4 + 5O_2 \longrightarrow P_4O_{10}$

(i) If 1 mole P_4 & 4 mole of O_2

(ii) If 3 mole P_4 & 11 mole of O_2

(iii) If 3 mole P_4 & 13 mole of O_2

33 **3.** By the reaction of carbon and oxygen, a mixture of CO and CO_2 is obtained. What is the composition (% by mass) of the mixture obtained when 20 grams of O_2 reacts with 12 grams of carbon ?

4. Nitrogen (N), phosporus (P), and potassium (K) are the main nutrients in plant fertilizers. According to

34-35 an industry convention, the numbers on the label refer to the mass % of N, P_2O_5, and K_2O, in that order. Calculate the N : P : K ratio of a 30 : 10 : 10 fertilizer in terms of moles of each elements, and express it as x : y : 1.0. Find y.

5. A 10 g sample of a mixture of calcium chloride and sodium chloride is treated with Na_2CO_3 to precipitate

36 calcium as calcium carbonate. This $CaCO_3$ is heated to convert all the calcium to CaO and the final mass of CaO is 1.12gm. Calculate % by mass of NaCl in the original mixture.

6. A mixture of Ferric oxide (Fe_2O_3) and Al is used as a solid rocket fuel which reacts to give Al_2O_3 and Fe. No other reactants and products are involved. On complete reaction of 1 mole of Fe_2O_3, 200 units of energy is released.

(a) Write a balance reaction representing the above change.

37 (b) What should be the ratio of masses of Fe_2O_3 and Al taken so that maximum energy per unit mass of fuel is released.

(c) What would be energy released if 16 kg of Fe_2O_3 reacts with 2.7 kg of Al.

7. 1 gm sample of $KClO_3$ was heated under such conditions that a part of it decomposed according to the equation

43

(1) $2KClO_3 \longrightarrow 2\ KCl + 3O_2$

and remaining underwent change according to the equation.

(2) $4KClO_3 \longrightarrow 3\ KClO_4 + KCl$

If the amount of O_2 evolved was 112 ml at 1 atm and 273 K., calculate the % by weight of $KClO_4$ in the residue.

Pg: 50-51

8. 5.33 mg of salt $[Cr(H_2O)_5Cl].Cl_2.\ H_2O$ is treated with excess of $AgNO_3$(aq.) then mass of AgCl ppt.obtained will be : Given : [Cr = 52, Cl = 35.5]

51

9. If mass % of oxygen in monovalent metal carbonate is 48%. Then find the number of atoms of metal present in 5mg of this metal carbonate sample is ($N_A = 6.0 \times 10^{23}$)

52

10. To find formula of compound composed of A & B which is given by A_xB_y, it is strongly heated in oxygen as per reaction-

$A_xB_y + O_2 \rightarrow AO + \text{Oxide of B}$

If 2.5gm of A_xB_y on oxidation gives 3gm oxide of A, Find empirical formula of A_xB_y,

[Take atomic mass of A = 24 & B = 14]

53

11. Calculate maximum mass of $CaCl_2$ produced when 2.4×10^{24} atoms of calcium is taken with 96 litre of Cl_2 gas at 380 mm pressure and at 27ºC.

[R : 0.08 atm L/mole-K & $N_A = 6 \times 10^{23}$]

54

12. $P_4S_3 + 8O_2 \longrightarrow P_4O_{10} + 3SO_2$

Calculate minimum mass of P_4S_3 is required to produce at least 1 gm of each product.

54-55

13. Consider the given reaction

$H_4P_2O_7 + 2NaOH \rightarrow Na_2H_2P_2O_7 + 2H_2O$

If 534 gm of $H_4P_2O_7$ is reacted with 30×10^{23} molecules of NaOH then total number of molecules produced in the product is

EXERCISE (O-I) Q1-30: In class (Some oral)

Single Correct :

PROBLEMS RELATED WITH DIFFERENT TYPES OF ATOMIC MASSES & BASIC CONCEPT OF MOLE

1. Which of the following has the Maximum mass ?

[In class]

(A) 1 g-atom of C (B) $\frac{1}{2}$ mole of CH_4

(C) 10 mL of water (D) 3.011×10^{23} atoms of oxygen

2. The number of molecules of CO_2 present in 44 g of CO_2 is :

[In class]

(A) 6.0×10^{23} (B) 3×10^{23} (C) 12×10^{23} (D) 3×10^{10}

3. The number of mole of ammonia in 4.25 g of ammonia is :

[In class]

(A) 0.425 (B) 0.25 (C) 0.236 (D) 0.2125

4. The charge on 1 gram ions of Al^{3+} is : (N_A = Avogadro number, e = charge on one electron)

[In class]

(A) $\frac{1}{27}N_Ae$ coulomb (B) $\frac{1}{3}\times N_Ae$ coulomb (C) $\frac{1}{9}\times N_Ae$ coulomb (D) $3\times N_Ae$ coulomb

5. The atomic weights of two elements A and B are 40u and 80u respectively. If x g of A contains y atoms, how many atoms are present in 2x g of B?

[In class]

(A) $\frac{y}{2}$ (B) $\frac{y}{4}$ (C) y (D) 2y

6. A sample of aluminium has a mass of 54.0 g. What is the mass of the same number of magnesium atoms? (At. wt. Al = 27, Mg = 24)

[In class]

(A) 12 g (B) 24 g (C) 48 g (D) 96 g.

7. The weight of a molecule of the compound $C_{60}H_{22}$ is :

[In class]

(A) 1.09×10^{-21} g (B) 1.24×10^{-21} g (C) 5.025×10^{-23} g (D) 16.023×10^{-23} g

8. The number of electron in 3.1 mg NO_3^- is -

[In class]

(A) 32 (B) 1.6×10^{-3} (C) 9.6×10^{20} (D) 9.6×10^{23}

9. A gaseous mixture contains CO_2 (g) and N_2O (g) in a 2 : 5 ratio by mass. The ratio of the number of molecules of CO_2 (g) and N_2O (g) is

[In class]

(A) 5 : 2 (B) 2 : 5 (C) 1 : 2 (D) 5 : 4

10. Which of the following contain largest number of carbon atoms?

[In class]

(A) 15 gm ethane, C_2H_6 (B) 40.2 gm sodium oxalate, $Na_2C_2O_4$

(C) 72 gm glucose, $C_6H_{12}O_6$ (D) 35 gm pentene, C_5H_{10}

11. The number of hydrogen atoms in 0.9 gm glucose, $C_6H_{12}O_6$, is same as

[In class]

(A) 0.048 gm hydrazine, N_2H_4 (B) 0.17 gm ammonia, NH_3

(C) 0.30 gm ethane, C_2H_6 (D) 0.03 gm hydrogen, H_2

12. The weight of 1×10^{22} molecules of $CuSO_4 . 5H_2O$ is :

[In class]

(A) 41.59 g (B) 415.9 g (C) 4.159 g (D) 2.38 g

13. The number of carbon atoms present in a signature, if a signature written by carbon pencil weights 1.2×10^{-3} g is

[In class]

(A) 12.04×10^{20} (B) 6.02×10^{19} (C) 3.01×10^{19} (D) 6.02×10^{20}

14. Ethanol, C_2H_5OH, is the substance commonly called alcohol. The density of liquid alcohol is 0.8 g/ml at 293 K. If 1.2 mole of ethanol are needed for a particular experiment, what volume of ethanol should be measured out?

[In class]

(A) 55 ml (B) 58 ml (C) 69 ml (D) 79 ml

15. 112.0 ml of NO_2 at 1atm & 273 K was liquefied, the density of the liquid being 1.15 gm/ml. Calculate the volume of and the number of molecules in the liquid NO_2.

[In class]

(A) 0.10 ml and 3.01×10^{22} (B) 0.20 ml and 3.01×10^{21}
(C) 0.20 ml and 6.02×10^{23} (D) 0.40 ml and 6.02×10^{21}

16. X gm A atoms on combining with Y atoms of B form 5 molecules of a compound containing A & B. Find the molecular weight of compound formed. (Atomic weight of B = M)

[In class]

(A) $\frac{(XN_A + MY)}{5}$ (B) $\frac{X + M}{5}$ (C) $\frac{X + MY}{5}$ (D) $\left(\frac{X + MYN_A}{5}\right)$

17. At same temperature and pressure, two gases have the same number of molecules. They must

[In class]

(A) have same mass (B) have equal volumes
(C) have a volume of 22.7 dm^3 each (D) have an equal number of atoms

18. An iodized salt contains 0.5 % of NaI. A person consumes 3 gm of salt everyday. The number of iodide ions going into his body everyday is

[In class]

(A) 10^{-4} (B) 6.02×10^{-4} (C) 6.02×10^{19} (D) 6.02×10^{23}

19. Equal volumes of oxygen gas and a second gas weigh 1.00 and 2.375 grams respectively under the same experimental conditions. Which of the following is the unknown gas?

[In class]

(A) NO (B) SO_2 (C) CS_2 (D) CO

20. Four 1-1 litre flasks are separately filled with the gases H_2, He, O_2 and O_3 at the same temperature and pressure. The ratio of total number of atoms of these gases present in different flask would be :

[In class]

(A) 1 : 2 :3 : 4 (B) 2 : 1 :2 : 4 (C) 2 : 1 :2 : 3 (D) 2 : 1 :2 : 3

STOICHIOMETRY

[In class]

21. For the reaction $2P + Q \rightarrow R$, 8 mol of P and excess of Q will produce :

(A) 8 mol of R (B) 5 mol of R (C) 4 mol of R (D) 13 mol of R

[In class]

22. If 1.5 moles of oxygen combine with Al to form Al_2O_3, the weight of Al used in the reaction is :

(A) 27 g (B) 40.5 g (C) 54g (D) 81 g

23. 74 gm of a sample on complete combustion gives 132 gm CO_2 and 54 gm of H_2O. The molecular formula of the compound may be
[In class]
(A) C_5H_{12} (B) $C_4H_{10}O$ (C) $C_3H_6O_2$ (D) $C_3H_7O_2$

24. The mass of CO_2 produced from 620 gm mixture of $C_2H_4O_2$ & O_2, prepared to produce maximum energy is (Combustion reaction is exothermic)
[In class]
(A) 413.33 gm (B) 593.04 gm (C) 440 gm (D) 320 gm

25. The minimum mass of mixture of A_2 and B_4 required to produce at least 1 kg of each product is :
(Given At. mass of 'A' = 10 ; At. mass of 'B' = 120)
[In class]
$$5A_2 + 2B_4 \longrightarrow 2AB_2 + 4A_2B$$
(A) 2120 gm (B) 1060 gm (C) 560 gm (D) 1660 gm

LIMITING REAGENT

26. The mass of Mg_3N_2 produced if 48 gm of Mg metal is reacted with 34 gm NH_3 gas is
$Mg + NH_3 \longrightarrow Mg_3N_2 + H_2$
[In class]
(A) $\frac{200}{3}$ gm (B) $\frac{100}{3}$ gm (C) $\frac{400}{3}$ gm (D) $\frac{150}{3}$ gm

27. The mass of P_4O_{10} produced if 440 gm of P_4S_3 is mixed with 384 gm of O_2 is
$P_4S_3 + O_2 \longrightarrow P_4O_{10} + SO_2$
[In class]
(A) 568 gm (B) 426 gm (C) 284 gm (D) 396 gm

28. Mass of sucrose $C_{12}H_{22}O_{11}$ produced by mixing 84 gm of carbon, 12 gm of hydrogen and 56 lit. O_2 at 1 atm & 273 K according to given reaction, is
[In class]
$C(s) + H_2(g) + O_2(g) \longrightarrow C_{12}H_{22}O_{11}(s)$
(A) 138.5 (B) 155.5 (C) 172.5 (D) 199.5

29. 0.5 mole of H_2SO_4 is mixed with 0.2 mole of $Ca(OH)_2$. The maximum number of moles of $CaSO_4$ formed is
[In class]
(A) 0.2 (B) 0.5 (C) 0.4 (D) 1.5

SEQUENTIAL & PARALLEL REACTIONS

30. 25.4 g of iodine and 14.2g of chlorine are made to react completely to yield a mixture of ICl and ICl_3. Calculate he number of moles of ICl and ICl_3 formed.
[In class]
(A) 0.1 mole, 0.1 mole (B) 0.1 mole, 0.2 mole (C) 0.5 mole, 0.5 mole (D) 0.2 mole, 0.2 mole

31. What weights of P_4O_6 and P_4O_{10} will be produced by the combustion of 31g of P_4 in 32g of oxygen leaving no P_4 and O_2.
38
(A) 2.75 g, 219.5 g (B) 27.5 g, 35.5 g (C) 55 g, 71 g (D) 17.5 g, 190.5 g

32. What weight of $CaCO_3$ must be decomposed to produce the sufficient quantity of carbon dioxide to convert 21.2 kg of Na_2CO_3 completely in to $NaHCO_3$. [Atomic mass Na = 23, Ca = 40]

39

$$CaCO_3 \longrightarrow CaO + CO_2$$
$$Na_2CO_3 + CO_2 + H_2O \longrightarrow 2NaHCO_3$$

(A) 100 Kg (B) 20 Kg (C) 120 Kg (D) 30 Kg

33. The following process has been used to obtain iodine from oil-field brines in California.

$$NaI + AgNO_3 \longrightarrow AgI + NaNO_3 \quad ; \quad 2AgI + Fe \longrightarrow FeI_2 + 2Ag$$

39-40

$$2FeI_2 + 3Cl_2 \longrightarrow 2FeCl_3 + 2I_2$$

How many grams of $AgNO_3$ are required in the first step for every 254 kg I_2 produced in the third step.

(A) 340 kg (B) 85 kg (C) 68 kg (D) 380 kg

34. 10 g of a sample of a mixture of $CaCl_2$ and NaCl is treated to precipitate all the calcium as $CaCO_3$. This $CaCO_3$ is heated to convert all the Ca to CaO and the final mass of CaO is 1.62 g . The percent by mass of $CaCl_2$ in the original mixture is.

40-41

(A) 32.1 % (B) 16.2 % (C) 21.8 % (D) 11.0 %

MISCELLANEOUS PROBLEM

35. 40 gm of a carbonate of an **alkali metal** or **alkaline earth metal** containing some inert impurities was made to react with excess HCl solution. The liberated CO_2 occupied 12.315 lit. at 1 atm & 300 K. The correct option is

41

(A) Mass of impurity is 1 gm and metal is Be

(B) Mass of impurity is 3 gm and metal is Li

(C) Mass of impurity is 5 gm and metal is Be

(D) Mass of impurity is 2 gm and metal is Mg

Pg 56

36. In chemical scale, the relative mass of the isotopic mixture of X atoms (X^{20}, X^{21}, X^{22}) is approximately equal to : (X^{20} has 99 percent abundance)

(A) 20.002 (B) 21.00 (C) 22.00 (D) 20.00

37. Calculate percentage change in M_{avg} of the mixture, if PCl_5 undergo 50% decomposition in a closed vessel. $PCl_5 \longrightarrow PCl_3 + Cl_2$

Pg 56-57

(A) 50% (B) 66.66 % (C) 33.33 % (D) Zero

Pg 71

38. A compound possess 8% sulphur by mass. The least molecular mass is :

(A) 200 (B) 400 (C) 155 (D) 355

39. The empirical formula of a compound of molecular mass 120 is CH_2O. The molecular formula of the compound is :

(A) $C_2H_4O_2$ (B) $C_4H_8O_4$ (C) $C_3H_6O_3$ (D) all of these

40. Calculate the molecular formula of compound which contains 20% Ca and 80% Br (by wt.) if molecular weight of compound is 200. (Atomic wt. Ca = 40, Br = 80)

(A) $Ca_{1/2}Br$ (B) $CaBr_2$ (C) CaBr (D) Ca_2Br

41. Cortisone is a molecular substance containing 21 atoms of carbon per molecule. The mass percentage of carbon in cortisone is 69.98%. Its molar mass is :

(A) 176.5 (B) 252.2 (C) 287.6 (D) 360.1

42. One gram of the silver salt of an organic dibasic acid yields, on strong heating, 0.5934 g of silver. If the weight percentage of carbon in it 8 times the weight percentage of hydrogen and one-half the weight percentage of oxygen, determine the molecular formula of the acid. [Atomic weight of Ag = 108]

(A) $C_4H_6O_4$ (B) $C_4H_6O_6$ (C) $C_2H_6O_2$ (D) $C_5H_{10}O_5$

43. The percentage by mole of NO_2 in a mixture of $NO_2(g)$ and $NO(g)$ having average molecular mass 34 is :

(A) 25% (B) 20% (C) 40% (D) 75%

EXERCISE (O-II)

ONE OR MORE THAN ONE MAY BE CORRECT :

1. Select the correct statement(s) for $(NH_4)_3PO_4$.

42

(A) Ratio of number of oxygen atom to number of hydrogen atom is 1 : 3
(B) Ratio of number of cation to number of anion is 3 : 1
(C) Ratio of number of gm-atom of nitrogen to gm-atoms of oxygen is 3 : 2
(D) Total number of atoms in one mole of $(NH_4)_3PO_4$ is 20.

2. 12 g of Mg was burnt in a closed vessel containing 32 g oxygen. Which of the following is not correct.

42

(A) 2 gm of Mg will be left unburnt.
(B) 0.75 gm-molecule of O_2 will be left unreacted.
(C) 20 gm of MgO will be formed.
(D) The mixture at the end will weight 44 g.

3. 50 gm of $CaCO_3$ is allowed to react with 68.6 gm of H_3PO_4 then select the correct option(s)-

44

$3CaCO_3 + 2H_3PO_4 \rightarrow Ca_3(PO_4)_2 + 3H_2O + 3CO_2$

(A) 51.67 gm salt is formed
(B) Amount of unreacted reagent = 35.93 gm
(C) $n_{CO_2} = 0.5$ moles
(D) 0.7 mole CO_2 is evolved

4. Industrially TNT ($C_7H_5N_3O_6$, explosive material) is synthesized by reacting toluene (C_7H_8) with nitric acid in presence of sulphuric acid. Calculate the maximum weight of $C_7H_5N_3O_6$ which can be produced by 140.5 gm of a mixture of C_7H_8 and HNO_3.

46-47

$C_7H_8 + 3HNO_3 \longrightarrow C_7H_5N_3O_6 + 3H_2O$

(A) 140.5
(B) 113.5
(C) $\frac{140.5}{2}$
(D) $140.5 - (3 \times 18)$

5. 'A' reacts by following two parallel reaction to give B & C If half of 'A' goes into reaction I and other half goes to reaction-II. Then , select the correct statement(s)

$A + N \xrightarrow{I} B + L$

$A + N \xrightarrow{II} \frac{1}{2}B + \frac{1}{2}(C) + L$

(A) B will be always greater than C
(B) If 2 mole of C are formed then total 2 mole of B are also formed
(C) If 2 mole of C are formed then total 4 mole of B are also formed
(D) If 2 mole of C are formed then total 6 mole of B are also formed

6. Silver metal in ore is dissolved by potassium cyanide solution in the presence of air by the reaction

$4\,Ag + 8\,KCN + O_2 + 2H_2O \longrightarrow 4\,K[Ag\,(CN)_2] + 4\,KOH$

(A) The amount of KCN required to dissolve 100 g of pure Ag is 120 g.
(B) The amount of oxygen used in this process is 0.742 g (for 100 g pure Ag)
(C) The amount of oxygen used in this process is 7.40 g (for 100 g pure Ag)
(D) The volume of oxygen used at STP is 5.20 litres.

7. Crude calcium carbide, CaC_2, is made in an electric furnace by the following reaction,

$$CaO + 3C \longrightarrow CaC_2 + CO$$

The product contain 85% CaC_2 and 15% unreacted CaO.

(A) 1051.47 kg of CaO is to be added to the furnace charge for each 1000 kg of CaC_2.

(B) 893.8 kg of CaO is to be added to the furnace charge for each 1000 kg of crude product.

(C) 708.2 kg of CaO is to be added to the furnace charge for each 1000 kg of CaC_2.

(D) 910.3 kg of CaO is to be added to the furnace charge for each 1000 kg of crude product.

8. Given following series of reactions:

(I) $NH_3 + O_2 \longrightarrow NO + H_2O$

(II) $NO + O_2 \longrightarrow NO_2$

(III) $NO_2 + H_2O \longrightarrow HNO_3 + HNO_2$

(IV) $HNO_2 \longrightarrow HNO_3 + NO + H_2O$

Select the correct option(s):

(A) Moles of HNO_3 obtained is half of moles of Ammonia used if HNO_2 is not used to produce HNO_3 by reation (IV)

(B) $\frac{100}{6}$% more HNO_3 will be produced if HNO_2 is used to produce HNO_3 by reaction (IV) than if HNO_2 is not used to produce HNO_3 by reaction (IV)

(C) If HNO_2 is used to produce HNO_3 then $\frac{1}{4}^{th}$ of total HNO_3 is produced by reaction (IV)

(D) Moles of NO produced in reaction (IV) is 50% of moles of total HNO_3 produced.

9. In the quantitative determination of nitrogen, N_2 gas liberated from 0.42 gm of a sample of organic compound was collected over water. If the volume of N_2 gas collected was $\frac{100}{11}$ ml at total pressure 860 mm Hg at 250 K, % by mass of nitrogen in the organic compound is

[Aq. tension at 250 K is 24 mm Hg and R = 0.08 L atm mol^{-1} K^{-1}]

(A) $\frac{10}{3}$% (B) $\frac{5}{3}$% (C) $\frac{20}{3}$% (D) $\frac{100}{3}$%

Assertion Reason:

10. **Statement -1** : $2A + 3B \longrightarrow C$

4/3 moles of 'C' are always produced when 3 moles of 'A' & 4 moles of 'B' are added.

Statement -2 : 'B' is the limiting reactant for the given data.

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.

(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1.

(C) Statement-1 is false, statement-2 is true.

(D) Statement-1 is true, statement-2 is false.

Match the column :

11. One type of artifical diamond (commonly called YAG for yttrium aluminium garnet) can be represented by the formula $Y_3Al_5O_{12}$.[Y = 89, Al =27]

	Column I		**Column II**
	Element		Weight percentage
(P)	Y	(1)	22.73%
(Q)	Al	(2)	32.32%
(R)	O	(3)	44.95%

12. The recommended daily dose is 17.6 milligrams of vitamin C (ascorbic acid) having formula $C_6H_8O_6$. Match the following. Given : $N_A = 6 \times 10^{23}$

	Column I		**Column II**
(A)	O-atoms present	(P)	10^{-4} mole
(B)	Moles of vitamin C in 1 gm of vitamin C	(Q)	5.68×10^{-3}
(C)	Moles of vitamin C that should be consumed daily	(R)	3.6×10^{20}

13. **Matching list type :**

	Column-I (mass of product)		**Column-II**
(P)	$2H_2 + O_2 \rightarrow 2H_2O$ (1g, 1g)	(1)	1.028 g
(Q)	$3H_2 + N_2 \rightarrow 2NH_3$ (1g, 1g)	(2)	1.333 g
(R)	$H_2 + Cl_2 \rightarrow 2HCl$ (1g, 1g)	(3)	1.125 g
(S)	$2H_2 + C \rightarrow CH_4$ (1g, 1g)	(4)	1.214 g

Code :

	P	Q	R	S
(A)	3	4	1	2
(B)	2	4	1	3
(C)	4	3	1	2
(D)	2	3	1	4

COMPREHENSION:

14. NaBr, used to produce AgBr for use in photography can be self prepared as follows :

$Fe + Br_2 \longrightarrow FeBr_2$ ....(i)

$FeBr_2 + Br_2 \longrightarrow Fe_3Br_8$ ....(ii) (not balanced)

$Fe_3Br_8 + Na_2CO_3 \longrightarrow NaBr + CO_2 + Fe_3O_4$ ....(iii) (not balanced)

(a) Mass of iron required to produce 2.06×10^3 kg NaBr

(A) 420 gm (B) 420 kg (C) 4.2×10^5 kg (D) 4.2×10^8 gm

(b) If the yield of (ii) is 60% & (iii) reaction is 70% then mass of iron required to produce 2.06×10^3 kg NaBr

(A) 10^5 kg (B) 10^5 gm (C) 10^3 kg (D) None

(c) If yield of (iii) reaction is 90% then mole of CO_2 formed when 2.06×10^3 gm NaBr is formed

(A) 20 (B) 10 (C) 40 (D) None

15. Preparation of cobalt Metaborate involves the following steps of reactions:

(i) $Ca_2B_6O_{11} + Na_2CO_3\,(aq) \xrightarrow{\text{Boiled}} CaCO_3$ (insoluble) $+ Na_2B_4O_7 + 2NaBO_2$

(ii) $Na_2B_4O7 \xrightarrow{\Delta} NaBO_2 + B_2O_3$

(iii) $CoO + B_2O_3 \xrightarrow{\Delta} Co(BO_2)_2$.

(Atomic weight : B = 11, Co = 59)

(a) Mass of $Ca_2B_6O_{11}$ in kg required to produce 14.5 kg of $Co(BO_2)_2$, assuming 100% yield of each reaction is

(A) 32.2 (B) 40 (C) 28.2 (D) 30

(b) If the yield of reaction (i), (ii) & (iii) is 60%, $\frac{200}{3}$ % & 32.2 % respectively, then mass of $Ca_2B_6O_{11}$ in kg required to produce 14.5 kg of $Co(BO_2)_2$ is

(A) 250 (B) 200 (C) 190 (D) 150

16. Water is added to 3.52 grams of UF_6. The products are 3.08 grams of a solid [containing only U, O & F] and 0.8 gram of a gas only. The gas [containing fluorine and hydrogen only], contains 95 % by mass fluorine.

[Assume that the empirical formula is same as molecular formula.]

(a) The empirical formula of the gas is

(A) HF_2 (B) H_2F (C) HF (D) HF_3

(b) The empirical formula of the solid product is

(A) UF_2O_2 (B) UFO_2 (C) UF_2O (D) UFO

(c) The percentage of fluorine of the original compound which is converted into gaseous compound is

(A) 66.66 % (B) 33.33 % (C) 50 % (D) 89.9 %

EXERCISE - JEE MAIN

P58 **1.** The weight of 2.01×10^{23} molecules of CO is– **[AIEEE 2002]**
(1) 9.3 g (2) 7.2 g (3) 1.2 g (4) 3 g

58 **2.** In an organic compound of molar mass 108 g mol^{-1} C, H and N atoms are present in 9 : 1 : 3.5 by weight. Molecular formula can be : **[AIEEE 2002]**
(1) $C_6H_8N_2$ (2) $C_7H_{10}N$ (3) $C_5H_6N_3$ (4) $C_4H_{18}N_3$

59 **3.** If we consider that 1/6, in place of 1/12, mass of carbon atom is taken to be the relative atomic mass unit, the mass of one mole of the substance will :- **[AIEEE-2005]**
(1) be a function of the molecular mass of thesubstance
(2) remain unchanged
(3) increase two fold
(4) decrease twice

59 **4.** How many moles of magnesium phosphate, $Mg_3(PO_4)_2$ will contain 0.25 mole of oxygen atoms?
(1) 3.125×10^{-2} (2) 1.25×10^{-2} (3) 2.5×10^{-2} (4) 0.02 **[AIEEE 2006]**

59 **5.** A transition metal M forms a volatile chloride which has a vapour density of 94.8. If it contains 74.75% of chlorine the formula of the metal chloride will be **[AIEEE 2012 (Online)]**
(1) MCl_2 (2) MCl_4 (3) MCl_5 (4) MCl_3

60 **6.** The ratio of number of oxygen atoms (O) in 16.0g ozone (O_3), 28.0 g carbon monoxide (CO) and 16.0g oxygen (O_2) is :-
(Atomic mass : C = 12, O = 16 and Avogadro's constant $N_A = 6.0 \times 1023$ mol^{-1})
[AIEEE 2012 (Online)]
(1) 3 : 1 : 1 (2) 1 : 1 : 2 (3) 3 : 1 : 2 (4) 1 : 1 : 1

61 **7.** A gaseous hydrocarbon gives upon combustion 0.72 g of water and 3.08 g of CO_2. The empirical formula of the hydrocarbon is **[JEE(Main)-2013]**
(1) C_2H_4 (2) C_3H_4 (3) C_6H_5 (4) C_7H_8

61 **8.** The ratio of masses of oxygen and nitrogen in a particular gaseous mixture is 1 : 4. The ratio of number of their molecule is : **[JEE(Main)-2014]**
(1) 1 : 8 (2) 3 : 16 (3) 1 : 4 (4) 7 : 32

61 **9.** The molecular formula of a commercial resin used for exchanging ions in water softening is $C_8H_7SO_3Na$ (Mol. Wt. 206) What would be the maximum uptake of Ca^{2+} ions by the resin when expressed in mole per gram resin? **[JEE(Main)-2015]**
(1) $\frac{1}{103}$ (2) $\frac{1}{206}$ (3) $\frac{2}{309}$ (4) $\frac{1}{412}$

62 **10.** In Carius method of estimation of halogens, 250 mg of an organic compound give 141 mg of AgBr. The percentage of bromine in the compound is : (at. mass Ag = 108; Br = 80)
[JEE(Main)-2015]
(1) 24 (2) 36 (3) 48 (4) 60

62

11. The most abundant elements by mass in the body of a healthy human adult are : Oxygen (61.4%) ; Carbon (22.9%), Hydrogen (10.0%) ; and Nitrogen (2.6%). The weight which a 75 kg person would gain if all ^1H atoms are replaced by ^2H atoms is **[JEE(Main)-2017]**

(1) 15 kg (2) 37.5 kg (3) 7.5 kg (4) 10 kg

62

12. 1 gram of a carbonate (M_2CO_3) on treatment with excess HCl produces 0.01186 mole of CO_2. the molar mass of M_2CO_3 in g mol^{-1} is : **[JEE(Main)-2017]**

(1) 1186 (2) 84.3 (3) 118.6 (4) 11.86

63

13. The reaction of mass percent of C and H of an organic compound ($C_XH_YO_Z$) is 6 : 1 , If one molecule of the above compound ($C_XH_YO_Z$)contains half as much oxygen as required to burn on molecule of compound C_XH_Y completely to CO_2 and H_2O. The empirical formula of compound $C_XH_YO_Z$ is : **[JEE(Main)-2018]**

(1) $C_2H_4O_3$ (2) $C_3H_6O_3$ (3) C_2H_4O (4) $C_3H_4O_2$

64

14. For the following reaction, the mass of water produced from 445 g of $C_{57}H_{110}O_6$ is:

$2C_{57}H_{110}O_6(s) + 163\ O_2(g) \longrightarrow 114\ CO_2(g) + 110\ H_2O(l)$ **[JEE(Main)-2019(Jan)]**

(1) 490 g (2) 890 g (3) 445 g (4) 495 g

64 65 68

15. A 10 mg effervescent tablet containing sodium bicarbonate and oxalic acid releases 0.25 ml of CO_2 at T = 298.15 K and p = 1 bar. If molar volume of CO_2 is 25.0 L under such condition, what is the percentage of sodium bicarbonate in each tablet ? [Molar mass of $NaHCO_3$ = 84 g mol^{-1}]

[JEE(Main)-2019(Jan)]

(1) 0.84 (2) 8.4 (3) 16.8 (4) 33.6

65

16. An organic compound is estimated through ~~Dumus~~ Dumas method and was found to evolve 6 moles of CO_2, 4 moles of H_2O and 1 mole of nitrogen gas. The formula of the compound is : **[JEE(Main)-2019(Jan)]**

(1) $C_6H_8N_2$ (2) C_6H_8N (3) $C_{12}H_8N_2$ (4) $C_{12}H_8N$

66

17. The percentage composition of carbon by mole in methane is : **[JEE(Main)-2019(April)]**

(1) 25% (2) 75% (3) 20% (4) 80%

66

18. For a reaction,

$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$; identify dihydrogen ($H_2$) as a limiting reagent in the following reaction mixtures. **[JEE(Main)-2019(April)]**

(1) 28 g of N_2 + 6 g of H_2 (2) 56 g of N_2 + 10 g of H_2

(3) 14 g of N_2 + 4 g of H_2 (4) 35 g of N_2 + 8 g of H_2

19. The minimum amount of $O_2(g)$ consumed per gram of reactant is for the reaction :

(Given atomic mass : Fe = 56, O = 16, Mg = 24, P = 31, C = 12, H = 1)

[JEE(Main)-2019(April)]

66

(1) $4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$

(2) $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$

(3) $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$

(4) $P_4(s) + 5O_2(g) \rightarrow P_4O_{10}(s)$

20. 5 moles of AB_2 weigh 125×10^{-3} kg and 10 moles of A_2B_2 weigh 300×10^{-3} kg. The molar mass of A(MA) and molar mass of B (MB) in kg mol^{-1} are:

[JEE(Main)-2019(April)]

67

(1) $M_A = 5 \times 10^{-3}$ and $M_B = 10 \times 10^{-3}$

(2) $M_A = 50 \times 10^{-3}$ and $M_B = 25 \times 10^{-3}$

(3) $M_A = 25 \times 10^{-3}$ and $M_B = 50 \times 10^{-3}$

(4) $M_A = 10 \times 10^{-3}$ and $M_B = 5 \times 10^{-3}$

21. 25 g of an unknown hydrocarbon upon burning produces 88 g of CO_2 and 9 g of H_2O. This unknown hydrocarbon contains: **[JEE(Main)-2019(April)]**

68

(1) 18 g of carbon and 7 g of hydrogen

(2) 22 g of carbon and 3 g of hydrogen

(3) 24 g of carbon and 1 g of hydrogen

(4) 20 g of carbon and 5 g of hydrogen

22. At 300 K and 1 atmospheric pressure, 10 mL of a hydrocarbon required 55 mL of O_2 for complete combustion, and 40 mL of CO_2 is formed. The formula of the hydrocarbon is:

[JEE(Main)-2019(April)]

69

(1) C_4H_7Cl (2) C_4H_{10} (3) C_4H_8 (4) C_4H_6

EXECISE - JEE ADVANCED

1. How many moles of e^- weight one Kg : **[JEE '2002 (Scr), 1]**

70

(A) 6.023×10^{23} (B) $\frac{1}{9.108} \times 10^{31}$ (C) $\frac{6.023}{9.108} \times 10^{54}$ (D) $\frac{1}{9.108 \times 6.023} \times 10^{8}$

2. Calculate the amount of Calcium oxide required when it reacts with 852 g of P_4O_{10}. **[JEE 2005]**

70

$6CaO + P_4O_{10} \longrightarrow 2\ Ca_3(PO_4)_2$

3. Given that the abundances of isotopes ^{54}Fe, ^{56}Fe and ^{57}Fe are 5%, 90% and 5%, respectively, the atomic mass of Fe is : **[JEE 2009]**

70

(A) 55.85 (B) 55.95 (C) 55.75 (D) 56.05

ANSWER KEY

EXERCISE (S-1)

1.	6.023×10^{13}	**2.**	1.99×10^{-23} g
3.	24g	**4.**	(i) $\frac{10^{20}}{N_A}$ moles ,(ii) 3200 amu , (iii) $14 \times 1.66 \times 10^{-24}$ g (iv) $3N_A$, $9N_A$, (v) $6N_A$
5.	3.2 g	**6.**	180 g
7.	2.5 g	**8.**	7.227×10^{24} .
9.	$10 \times 6.023 \times 10^{23}$, $8 \times 6.023 \times 10^{23}$, $8 \times 6.023 \times 10^{23}$.		
10.	68 mole	**11.**	5.34×10^{6} .
12.	20 N_A	**13.**	**292 g**
14.	2270 L	**15.**	7.5 moles
16.	24	**17.**	58.8 g
18.	27.6 gm	**19.**	1.0×10^{19}
20.	**3**	**21.**	50.14 L
22.	(i) 1/6 mole (ii) 5/12 mole	**23.**	0.48
24.	0.1185	**25.**	0.25 mole
26.	9.5	**27.**	w_c = 24 gm ; W_{CCl_4} = 154 gm
28.	5.6	**29.**	Al = 60%; Mg = 40%
30.	$CaCO_3$ = 28.4%; $MgCO_3$ = 71.6%	**31.**	$NaHCO_3$ = 14.9 %; Na_2CO_3 = 85.1 %
32.	42 g	**33.**	63 % , 37%
34.	10 %	**35.**	12.3
36.	39.18	**37.**	4.48 litre
38.	61.5 gm	**39.**	19.4 gm
40.	(a) 0.050 mol , (b) 0.050 mol	**41.**	640.0
42.	441 gm	**43.**	(a)59.17 gm (b) 61.97 gm
44.	1.14 gm	**45.**	0196
46.	92.7 gm/mole	**47.**	35.4527
48.	10	**49.**	$C_6H_4C_{12}$ **50.** 4

EXERCISE (S-II)

1. 12.9 gm
2. (i) 0.5 , 0.5 ; (ii) 2, 1 (iii) 1, 2
3. % CO = 65.625 ; % CO_2 = 34.375
4. 10 : 0.66 : 1
5. %NaCl = 77.8%
6. (i) $Fe_2O_3 + 2\,Al \longrightarrow Al_2O_3 + 2Fe$; (ii) 80 : 27; (iii)10,000 units
7. 59.72%
8. Ans. 5.74 gm

   $[Cr(H_2O)_5Cl].Cl_2.\ H_2O + 2AgNO_3(aq.) \longrightarrow 2AgCl\downarrow + [Cr(H_2O)_5Cl](NO_3)_2$

   0.02 mol　　　　　　　　0.04 mol
9. Ans. 6×10^{20}

   $M_2CO_3 \Rightarrow 48 = \left(\frac{48}{2M+60}\right) \times 100 \Rightarrow 2M + 60 = 100$, M 200

   $n = \frac{5\times10^{-3}}{100} = 5 \times 10^{-5}$ mol

   $n_M = 10 \times 10^{-5}$ mol $= 10^{-4}$ mol

   $n0_M = 6.00 \times 10^{19}$ atoms
10. Ans.(A_3B_2)

   $\frac{2.5}{24x+14y} \times x = \frac{3}{40} \times 1$
11. 222 gm
12. 1.1458
13. 7.5 × Na

EXERCISE (O-I)

1.	A	2.	A	3.	B	4.	D	5.	C
6.	C	7.	B	8.	C	9.	B	10.	D
11.	C	12.	C	13.	B	14.	C	15.	B
16.	A	17.	B	18.	C	19.	C	20.	C
21.	C	22.	C	23.	C	24.	C	25.	A
26.	A	27.	B	28.	B	29.	A	30.	A
31.	B	32.	B	33.	A	34.	A	35.	B
36.	A	37.	C	38.	B	39.	B	40.	B
41.	D	42.	B	43.	A				

EXERCISE (O-II)

1.	A,B	2.	A	3.	A,B,C	4.	B	5.	A,D
6.	A,C,D	7.	A,B	8.	A,C,D	9.	A	10.	C

11. (A)→R; (B)→P; (C)→Q
12. (A)→R; (B)→Q; (C)→P
13. A
14. (a) B (b) C (c) B
15. (a) A (b) A
16. (a) C (b) A (c) A

EXERCISE - JEE MAIN

1.	(1)	**2.**	(1)	**3.**	(2)	**4.**	(1)	**5.**	(2)
6.	(4)	**7.**	(4)	**8.**	(4)	**9.**	(4)	**10.**	(1)
11.	(3)	**12.**	(2)	**13.**	(1)	**14.**	(4)	**15.**	(2)
16.	(1)	**17.**	(3)	**18.**	(2)	**19.**	(1)	**20.**	(1)
21.	(3)	**22.**	(4)						

EXERCISE - JEE ADVANCED

1.	(D)	**2.**	1008 g	**3.**	(B)